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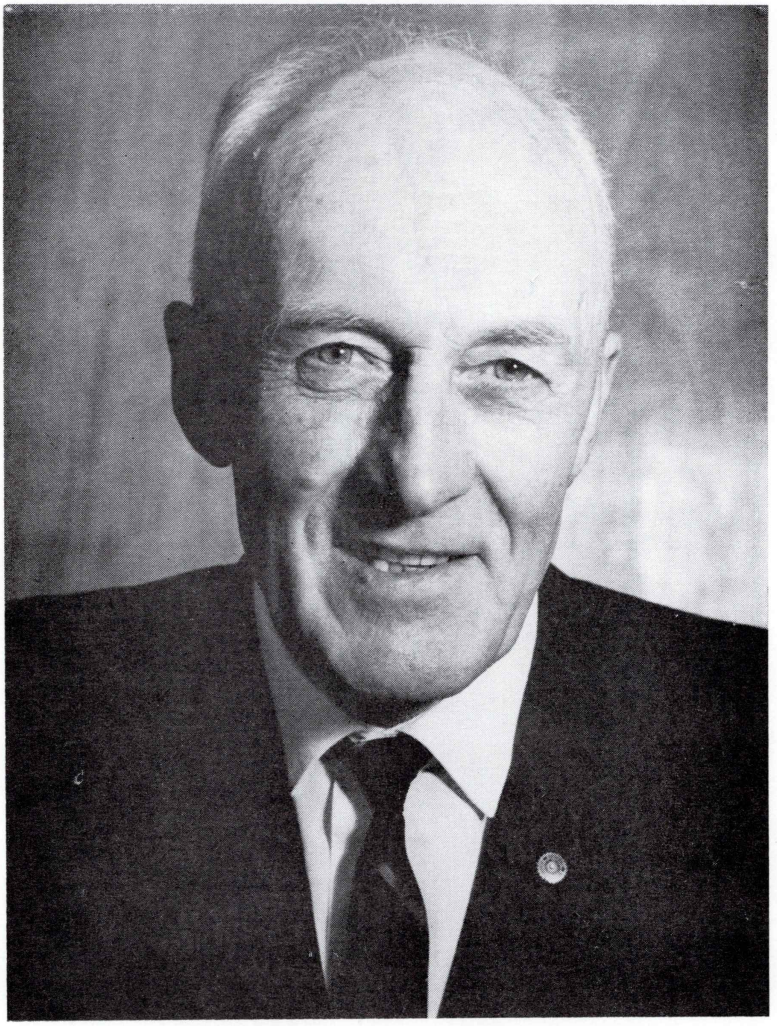

C. L. WALTER, D.S.O., J.P.,
C.ENG., M.I.E.E., M.N.Z.I.E.

PRESIDENT 1965-67

TRANSACTIONS

OF THE

THIRTY - EIGHTH

ANNUAL CONFERENCE

OF THE

Electric Supply Authority Engineers' Institute of New Zealand Inc.

Held in Christchurch, New Zealand, 25 to 28 September, 1967

This Institute as a body is not responsible for statements made in the following pages, and the opinions expressed by individual members have not necessarily been adopted as the unanimous opinion of the Institute.

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1967

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PRESIDENTIAL ADDRESS

"Electricity and Living"

C. L. WALTER, D.S.O., J.P., C.Eng., M.I.E.E., M.N.Z.I.E.
(Engineer-manager, Central Waikato E.P.B.)

AT the conclusion of one's term as your president it is traditional that he address you on some matters concerned with electricity supply. I propose to deal generally with items of interest connected with the usage of electricity in the past, the present and the future.

From time immemorial man has always endeavoured to achieve greater efficiencies in his living in order to obtain increased comfort, health and security. Over the past century considerable progress has been made in these directions and, particularly in the more advanced countries, this progress continues at an increasing rate.

In New Zealand over the past 50 years electricity has contributed very largely to our progress in minimising the human effort and raising the efficiency of human labour and the quality of its product. When we consider that a kilowatt-hour commonly called a unit, is approximately equivalent to two men each working an eight-hour day and then look at the kilowatt-hours per annum used in this country, we then can realise the many slaves we use in the form of electrical energy and how cheap it all is.

Electricity is now commonly used in all forms of human activity, in the factory, the office, the home and on the farm, and to a major degree is responsible for the conservation of human effort, both physical and mental, by mechanisation, automation and electronic computers. In addition to replacing manpower and increasing production, automatic control results in products of a more uniform and, usually, higher quality. Electronic machines are considerably faster and more accurate than the human brain, and the uses to which they can be put are almost infinite.

When electric supply was introduced generally in this country, in the early 1920s, most domestic installations consisted of only a few lights and a plug-socket for the electric iron. This was because the tariffs, although cheap, were such that further uses were considered a luxury and also because the range of electrical appliances was very limited. Today with electricity available to 99.6% of the population, 75% of the domestic consumers use an electric range and 79% an electric water-heater.

Existing industry was slow to adopt electricity as the power to drive its machines largely because the prime mover, usually a gas engine, was doing the job and also because of the reluctance of its owner to spend the money in replacing it. However, industries then coming into being did not hesitate. Others followed and today few, if any, do not employ electricity. Particularly is this the case in the dairy industry, where electricity has taken away all the drudgery.

In those distant days electricity although cheap was comparatively more expensive than is the case today. The overall average charge per kilowatt-hour in 1925 was 1.55d and for the year ended 31 March 1966 it was 1.345d.

It must be remembered that the average weekly wage in 1925 was approximately one-third of that obtaining today. Therefore, comparatively, the cost of electricity today is less than one-third of the cost in 1925.

One occasionally hears it said that electricity is too cheap but I feel sure that few, if any, of us will agree with that, for as supply authority engineers our task is to provide the electricity supply to the consumer at the cheapest possible cost.

It is of interest to note the increasing usage of electricity in the home over the seven years up to 1966 (Table I.)

Table I shows that the average consumption per domestic consumer increased from 4465 kWh in 1960 to 6203 kWh in 1966, an increase of almost 39%. This increase is partly accounted for by the additional number of all-electric homes. However, if we examine the individual consumer usages in our respective authorities, we find that because of the adoption of more electrical appliances most have increased consumptions per household year by year. This rate of growth must express a desire for a higher living standard and will no doubt continue for some years, if not indefinitely.

TABLE I—AVERAGE ANNUAL DOMESTIC CONSUMPTION

Year ended 31 March	*Kilowatt-hours*
1960	4465
1961	4620
1962	4890
1963	5100
1964	5590
1965	5800
1966	6203

The electricity supply industry is frequently referred to as the biggest business in New Zealand. This is not without justification, for in providing the supply the total capital outlay at 31 March 1966 was $797 million of which $123 million was outlayed by supply authorities. Over a period of approximately 50 years most of this money has been spent in providing the population of New Zealand with electricity which at present involves an annual working cost of $92 million. To cater for the required supply anticipated over the next five years it is estimated that a capital expenditure of approximately $412 million will be necessary for the generating and transmission requirements. Added to this will be the capital expenditure by supply authorities to distribute the power to the consumers, estimated to be $108 million.

As we in the industry all know, it is the electricity consumer who pays the cost of his supply from the generating station to his own installation. In other words, the electricity supply industry is financially self-contained. I make no apology for repeating this, for too often we hear of statements, attributed to responsible people, that the electric supply industry is a charge on the taxpayer.

Many supply authorities have already provided a sub-transmission system of from 33 kV to 50 kV in order that bulk power can be available economically at vantage points in their respective systems. With the increasing demand for power more and more large substations will be required. These substations, with their essential transmission lines, require large amounts of capital, and we as engineers are conscious of our responsibility to determine that the money spent ensures a satisfactory supply to the consumer at the minimum cost.

There is an increasing public aversion here to the presence of generating stations and transmission lines that provide

the power which society demands and depends on for comfortable and cheap living. This aversion is in striking contrast to the attitude of some developing countries whose inhabitants point with pride to their stations and power lines as symbols of progress. In New Zealand, however, we rightly place a high value on our national heritage and scenic beauty, but electricity is not yet available in such a convenient form that generating and transmitting media can be made completely invisible. A balanced attitude on this must be kept in mind in order that the cost of power does not become unrealistic.

FUTURE APPLICATIONS

Despite the high standard that we have obtained in the use of electricity there are still avenues for further uses. One of the more important ones could be in the farming industry which is important in that it contributes over 90% of the value of our exports and for which, in return, we are able to import those overseas goods on which we are dependent. Many applications of the use of electricity were effectively portrayed in this Institute's Symposium on Electrofarming in 1963, and it is pleasing to see that it has recently been brought up to date and reprinted as an E.D.A. booklet.

Electrofarming

In the dairying field electricity has made a major contribution in increasing the effectiveness of the human effort and improving the quality of the product. The ratio of cost advantage between electricity and labour will no doubt continue to increase, which will be an incentive, if not a compulsion, to mechanise further operations and processes.

A few years ago our Institute, with the Department of Agriculture, took steps to improve the hygienic standard of milking sheds with the provisions of an ample supply of near-boiling water. This quickly proved a success.

A later development was the quick chilling of milk and holding it at a low temperature until collected by a tanker. This further improved the quality of the milk delivered by minimising the growth of bacteria which would have occurred at normal temperature. Such improvements have increased the popularity of our dairy produce in the overseas markets.

I have often wondered why space-heating in milking sheds, to provide comfort for both operators and animals, has not been adopted to a greater extent. Probably it is because of a lack of capital, most of which is used to provide other things that more obviously contribute to greater production.

In the United Kingdom floor warming is used in operator pits and cow standings and in the ramps leading to and from the milking shed. A few sheds in New Zealand have installed space-heating and no doubt with time it will increase in popularity.

Irrigation of pastures has been carried out on many farms with real benefit to the farmer. One farmer in my Board's area claims that irrigation over the dry months increases his annual production by 10%. Irrigation can be used effectively as a controlled load which, being required during summer months, makes it a desirable load from the supply authority viewpoint.

Domestic

In the domestic field, comfort heating is increasing in popularity. Storage heaters with a low-rate off-peak tariff have much to commend them to all concerned. Like the storage water-heating load, this load would do much to improve the load factor which contributes so much to keeping the cost of electricity cheap. However, to ensure comfort and economy to the consumer, heat insulation of at least the ceilings of the buildings where such as storage heaters are intalled, should be a requirement. Years ago for the same reason this industry made it mandatory to have storage water-heating cylinders adequately heat insulated, the results of which have been and continue to be most satisfactory.

The electric supply industry will undoubtedly experience greater competition from other fuels, such as oil and gas, and it behoves us to further establish electricity as an attractive heating agent.

Air conditioning

In New Zealand we have only in recent years become aware of the ease with which air conditioning in offices and commercial premises can be obtained. In parts of the United States of America this application of electricity has become so popular that it is responsible for a midday peak on a hot summer day. In New Zealand it would not have cause to attain popularity to that extent, but it would certainly increase personal comfort during the height of summer in the northern areas.

Air conditioning could be beneficially adopted where the environment requires sealed double-glazed windows because of dust, fumes and traffic noise. Results of air conditioning in the U.S.A. have shown that with the increased employee comfort and morale, work production increased 9.5%, errors decreased 0.9% and absenteeism decreased 2.5%.

Electric vehicles

In the field of transportation technology has recently proved the possibility of battery-powered vehicles with a range of 40 miles and capable of speeds up to 40 miles/hour. Their price in the United Kingdom is about £350, and the running cost is equivalent to approximately 170 miles per gallon of petrol. Such electric vehicles would be an attractive means of moving large numbers of people, for instance the daily commuters, quickly and silently and without contaminating the atmosphere with exhaust fumes. Their use would also lessen the call on our overseas funds.

Further progress in this field by the United Kingdom Electricity Council who have now invited tenders for the supply of such vehicles, will be followed with interest. Night charging of their batteries would be an attractive load, which is estimated to lie between 100 and 200 kWh per week. Also in the United Kingdom, electric scooters, costing about £150 and with a range of 15 miles, are about to be introduced.

Continuity of supply

The increasing dependence on electric power creates an increased premium on system reliability. Electricity is today a way of life and very few operations can be carried out without it. Generally the supply is taken for granted until it is interrupted, when because of the dependence upon it, the routine of life becomes completely disorganised.

From periodicals and newspapers we have learned of the chaos that resulted in the U.S.A. when supply was interrupted on two occasions within recent years. Millions of people were affected and to a magnitude that fortunately could not happen here. However, the local effect, even though on a smaller scale would be the same as that in the States.

We are all aware of the disorganisation and loss to industry when it is deprived of electricity. To the domestic consumer his dependence on electricity, including the growing importance he places on use of his radio and television sets, makes any interruption extremely irksome.

Many of us recall the days of power restrictions when, instead of giving our traditional service to consumers, we had to work long hours to curtail the usage of electricity. Although it is only eight years since power was so restricted it would now be extremely difficult and most unpopular to implement rationing and restrictions.

For some years it has been apparent that people, in their desire for a higher living standard, are prepared to pay more and more, within reasonable limits, for power. It is therefore essential that an ample and continuous supply of electricity be always maintained, even though extra costs over that of providing for a more restricted supply are involved.

In an endeavour to increase the reliability of supply many of us have taken steps to introduce live-line or hot-line working so that work can be carried out without interrupting the supply.

Unfortunately the adoption of this practice has been delayed pending satisfactory arrangements with all concerned. For the benefit of the consumers it is hoped that this practice can be implemented soon and so minimise the irksome interruptions in supply when it becomes necessary to replace faulty equipment.

Load factor

Load factor has an important effect on the cost of purchasing and distributing power, and throughout New Zealand there is scope for improvement in the load factors of our respective systems.

The total cost of management and operation is fairly constant and independent of load factor, but the cost of power delivered decreases as the load factor increases. Furthermore if the maximum demand can be kept to a minimum by encouraging off-peak load the distribution losses are also minimised. Electricity, as such, cannot be stored but it can be converted into other forms of energy, such as heat, and stored during off-peak hours for use later when required.

As an industry providing a continuous service we are fortunately placed to encourage load away from peak hours. The shortest cut to a price reduction is an improvement in the load factor.

Technical Staff

At our conference last year we listened to an interesting and thought-provoking address from Dr A. G. Bogle, Professor of Electrical Engineering at the Ardmore School of Engineering. In summing up he said: "The senior engineering posts in the power supply industry are important professional posts with an unusually high degree of technical responsibility". Let us ever remember that our responsibility is of a high order in planning and operating our respective systems economically with adequate capacity to ensure a satisfactory and reliable service at the cheapest cost.

Dr Bogle also told us that engineers are often wasted on work that should be carried out by technicians. That unfortunately is true to a limited degree because of the ever-increasing shortage of technicians.

It is a matter of some concern to the electrical supply industry that not only is the shortage of technicians increasing but so too is the shortage of junior professional engineers. The planning, design and installation of the work necessary to supply the ever-increasing demand for power will be seriously impeded if engineers and technicians with the requisite knowledge are not available. Encouragement to selected personnel to train and qualify in these categories would considerably benefit our industry.

The Word Power Conference

Last year I was privileged to represent this Institute at the Sectional Meeting of the World Power Conference in Tokyo and I take this opportunity of thanking you for that privilege. It was an impressive and memorable experience.

The salient feature of the Conference was the increasing demand in all countries for power in all forms of energy and the awareness of the need for having that power available to cater for the increasing populations together with their increasing living standards.

The great advancements achieved in industry in Japan and in the living standards of the Japanese people during the last twenty years are evidence of this trend. Electricity is playing a major part in these achievements and the country is very conscious of the necessity to have engineers and technicians trained to keep abreast with the increasing requirements. That technological progress is essential to economic growth was very evident in Japan.

Conclusion

The key to further improvement in our standard of living undoubtedly lies in the greater application of electric power to the source of our national economy, agriculture and industry in particular.

This will bring increased responsibility to the electrical engineering profession and industry for on their wisdom and application will largely depend the economic well being and happiness of our society. I have every confidence in the future.

Vote of Thanks

P. A. GRIFFIN: Soon after one meets Mr Walter one holds him in high esteem on account of his gentlemanly qualities.

We who have the privilege of sharing with him his chosen profession, esteem him on account of his profound knowledge of his subject, the quality of his engineering, the depth of his experience, the wisdom of his judgment and his willingness to share his knowledge with all who seek his advice.

As one who has had the privilege of serving as one of his assistants I am aware of his great concern for the personal welfare of those around him, his staff, his profession, and indeed all humanity.

Reflecting on my experience while serving under him, I have no vivid recollection of being told to do this, or to do that, or not to do this, or not to do that, but rather an awareness of the existence of some mysterious guidance system which placed one firmly on the rails and inspired one to give of his best without the transmission or orders. This applied not only to our everyday task at work, but also in the sphere of personal conduct and facing the human problems of life.

We would all acknowledge that this talent is given to but a few of those who have been chosen to be the leaders of men. The address that Mr Walter has delivered to us today reflects much of his own personal approach to life—modesty and humility in his past achievements and a desire to give service to his fellow men in the future.

This address brings to us inspiration and encouragement to seek ways and means of perfecting and extending all the qualities of electricity to our fellow men, our consumers, to the credit of our respective authorities and to the enhancement of our profession.

I deem it a very great honour to have the privilege of moving a hearty vote of thanks to Mr Walter for his address today, and to request from him his permission to have it printed and recorded in our *Transactions*. I would ask you to join with me in approving this resolution and in expressing our appreciation to him, in the usual manner.

"Divided We Fall"

L. KAY, Ph.D., B.Sc., C.Eng., F.I.E.E., M.I.E.R.E.
(Professor of Electrical Engineering, University of Canterbury)

DURING the past 10 years growing attention has been given to the training of engineers in the United Kingdom. Colleges of Advanced Technology were formed out of the larger technical colleges, where new courses leading to "The Diploma in Technology" were started. These courses were intended to be of honours degree standard but were a significant departure from the traditional University course. In the main, students were recruited by industry and they alternately spent six months in the college and six months in industry* undergoing both academic and practical training. The courses were called "sandwich courses" and most were of four years' duration. It should be remembered that because of the different entrance standard in the United Kingdom the university course is normally of three years' duration, each academic year lasting for about 30 weeks. The sandwich-course students therefore received very much the same amount of academic training as the university students.

The reason for the introduction of sandwich courses was to meet the growing demand for technologists in the various industries in the United Kingdom. As these sandwich courses became established more Colleges of Technology started them. Special permission had to be obtained for each individual course, such as, for example, Mechanical Engineering, Electrical Engineering, Applied Chemistry, Applied Physics. This pattern developed rapidly, until in 1963 the Robbins Report suggested that the 10 Colleges of Advanced Technology became Universities and that a few of the regional colleges amalgamated with other larger institutions.

The new technological universities are now free to pursue whatever course they wish, whereas in the earlier days they were obliged to run sandwich courses under the Department of Education. The regional colleges (soon to be called polytechnics) are now also able to run courses of their own choosing, under a new body called the Council for National Academic Awards (C.N.A.A.) which can award degrees in almost any subject. Many of the new universities are continuing to run sandwich courses but they have, in addition, introduced full-time courses. This, however, has not reduced the great emphasis on practical training for the engineer. In 1965 the Committee on Manpower Resources for Science and Technology in the United Kingdom set up a Working Group on Engineering Training and the Requirements of Industry under the chairmanship of G. S. Bosworth. This group studied the education and training requirements for the electrical and mechanical manufacturing industries. Their recommendation was:

"Industry and education should collaborate in devising matching sections of education and training designed to ensure the efficient conversion of the university graduate into an effective industrial technologist, and which will attract a higher proportion of the ablest graduates into industry."

Their emphasis is on "matching sections" and what is the relevance of this to New Zealand and, in particular, to the power supply authorities?

New Zealand society will unquestionably follow the pattern of advanced societies elsewhere in the world, particularly those of the technological societies, because it is there where the standard of living is highest. True, New Zealand's economy is based on primary produce and not technology, but this is because in the past there has been an adequate demand for her products to maintain an increasing standard of living. Can we be sure that this will continue? The means for maintaining a high standard of living may well change and become technologically based at least in part, but we must at present assume that it will continue to improve. If so, the demand for electricity will continue to increase as it has in the past at probably an increasing rate as the population grows. The demand for engineers to service the industry will also increase. If, however, we look at the trend of recruitment, we see that fewer and fewer students are choosing to study heavy-current electrical engineering as opposed to light-current electrical engineering. At Canterbury last year, for example, the proportion who chose the Power option compared with those who chose the Communication option was about 1 to 4. Ten years ago, there was no Communication option. Can we afford to allow this trend to continue unchecked? The answer is obviously "NO". But what is actually being done about it, and why, in fact, does it exist at all?

Professor Bogle, in speaking to you last year, suggested one reason by questioning the professional status of the power supply engineer. His address served a very useful purpose by drawing your attention to what I, too, believe to be a very serious situation. This year I wish to do something positive by showing you what might be done to improve the situation. Many factors are involved.

Training

One of the outstanding factors I believe to be the apparent lack of interest in the training of engineers outside the universities and large Government establishments, such as the N.Z. Electricity Department, and the Post Office. Even in these Departments I consider the training of engineers to be somewhat out of date when compared with the efforts which are being made in the United Kingdom to improve the standards and methods of training. Little account is taken of the fact that a graduate on leaving university in New Zealand has already spent the equivalent of nine months on industrial training together with a period of workshop training at a technical institute.

The type of engineer required by the supply authorities is unusual compared with most other employers. The supply authority engineer has to deal for the most part with people. The demands on his technical knowledge are relatively small. If he has no real interest in people, he is unlikely to exhibit a lasting interest in his job. Elsewhere, an engineer's technical ability is paramount—at least in the years following graduation. Later, if he develops into an administrator or moves up to the executive level, then his ability to handle people becomes much more important, but this has already shown up as a natural trend, otherwise he would not have achieved this level. The executive or the administrator in industry usually chooses this vocation whereas the power supply engineer does

* In this context "industry" means those organisations outside University and Government research establishments.

not do so directly. He chooses a technical vocation and finds that he is faced with administration.

University education

The young student entering a university engineering school expects to learn about electrical engineering, mechanical engineering, etc., according to choice and it is the university's duty to teach him according to the latest knowledge, and encourage him to think as broadly as possible and as deeply as possible in his chosen subject. Considerable emphasis must be placed on the fundamentals of his subject with much less attention being paid to practical details which change with time. It may be useful here to re-emphasise the definition of a professional engineer, which is almost universally accepted.

"A professional engineer is competent by virtue of his fundamental education and training to apply the scientific method of outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research, designing, construction, manufacturing, superintending, managing and the education of the engineer. His work is predominantly intellectual and varied and not of a routine mental and physical character. It requires the exercise of original thought and judgment and the ability to supervise the technical and administrative work of others.

His education will have been such as to make him capable of continuously following progress in his branch of engineering science by consulting newly published work on a world-wide basis, assimilating such information, and applying it independently. He is thus placed in a position to make contributions to the development of engineering science or its applications. His education and training will have been such that he will have acquired a broad and general appreciation of the engineering sciences as well as a thorough insight into the special features of his own branch. In due time he will be able to give authoritative technical advice and to assume responsibility for the direction of important tasks in his branch."

From this it is clear where the responsibility for the University lies. It is important to note that he is expected to have acquired a broad and general appreciation of the engineering sciences as well as thorough insight into special features of his own branch. Twenty years ago, electrical engineering as taught in universities did not itself have any branches. Today, there are three main branches: Power, Communications, and Control, each encompassing more material than the combined subjects of those bygone days. Whereas at one time the electrical engineer would spend a considerable amount of his time studying mechanical and civil engineering subjects, he now has to spend time studying the two branches in which he is not choosing to specialise. Much less time therefore can be devoted to mechanical or civil engineering. The old idea that the electrical engineer must also be a mechanical and civil engineer is gone. In addition, the graduate now faces new developments which involve a considerable amount of physics. It is necessary for him therefore to study physics in much greater depth. The end product, in consequence, is very different from that of even 10 years ago.

Returning to the adverse trend in recruitment of graduates to the power supply industry, it will be seen that an unfavourable image is being presented to the graduate engineer because the knowledge that he has gained does not seem to be in keeping with the conventional pattern which supply authorities seem to maintain. This trend is universal; it is not only applicable to New Zealand. But elsewhere a lot is being done to try and arrest it. Much is being done in the universities.

New course

Let me illustrate this by showing you the new course which has been started at Canterbury.

During the First Professional Year there are five main subjects: Mathematics, Physics, Mechanics, Electrical Engineering, and Drawing and Design. Physics is a new addition. Students will study basic physics to a higher level than they have studied it in the past. Drawing and design has changed in character. It is a non-examinable subject but students must make satisfactory progress in their drawing to proceed to the subsequent years. This is being rigidly enforced with surprising cooperation from the students. Their drawing is related to electrical problems and not general mechanical problems. The aim of the course is to show them how to communicate on paper.

The electrical engineering material has changed considerably; much emphasis is placed on the fundamentals of circuit theory and these are studied initially in the time domain rather than the frequency domain which was common in the past. Electromagnetic theory is important and so also is electromechanical conversion. We do not at this stage refer to machines. An important new addition is Descriptive Electrical Engineering. Students are shown the relationship between power systems, communication systems, control systems, their basic theory, and where it will lead them. At the end of the two terms it is hoped that through this section of the course the student will have some understanding of the scope of electrical engineering.

At the end of this first year the student is guided into one of two courses, an Honours course and an Ordinary course, according to ability. The pace of the courses will be different and so also will be their content. The object is to train both innovators and consolidators; that is, those people who look into the future and produce the new ideas, start the new developments, and those people who take over the developments, put them into practice and use them to the best advantage. I am careful here not to use the words "research" and "manufacture".

The second year subjects include further Physics, Mechanics, and Mathematics. Electrical engineering is broken down into five parts: Circuit theory, field theory or electromagnetic theory, electronics, systems theory or control and machines. In the final year the Honours students will spend a considerable time on a project; at least one whole day each week. They will choose two of the three branches, Power Systems, Control Systems, or Communication Systems, and the emphasis will be on systems engineering. The Ordinary student will study more electronics because the pace at which he has been studying will be slower; he will compulsorily study control and will choose to specialise in either power transmission and distribution, or telecommunications. All students will spend approximately three hours a week on general studies, which could easily be entitled "The Technologist and Society". They will all study the principles of design.

This new course may be looked upon as a fairly drastic change from the course which was in existence some two or three years ago. To me it is not a drastic change; I have only introduced the course that I started in England two years ago under the C.N.A.A. Many of the things that we will teach in the future have been taught in the past here, but came under different subject titles. A change in course does not always mean a change in material, unless the lecturer himself makes this change. This ensures gradual change, although on paper it may appear that rapid change is taking place. Then if we look at the education and training requirements of the new Council of Engineering Institutions, we find that the approach at Canterbury is very much in keeping with their own recommendations. I would have been very disappointed had this not been so since I am familiar with the trends in British Universities, and the Council of

Engineering Institutions merely reflect these. I am confident therefore that the course in Canterbury will continue to be recognised by the Council of Engineering Institutions and, in particular, the Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers.

At the beginning of my address I referred to "heavy current" engineering and "light current" engineering. I have not used this since; it does not appear in the new course structure. We no longer believe that they exist as separate disciplines. We hope to show students that similar principles apply to all three branches of electrical engineering and that ideas found in one have application in others. The power systems engineer will study system theory in much the same way as the communication engineer. Much of it will be based on modern circuit theory. As electrical engineers we are really only concerned with the conversion and distribution of energy and information.

At postgraduate level, students studying power systems will be as familiar with computers and information theory as will those who are studying communication systems. They will both have an interest in electronics and use high grade instrumentation freely. We will in fact be making power engineering an interesting subject. I think this is the real crux of the matter. If the subject is interesting, and if the job subsequently is seen to be interesting, there will be no real difficulty in recruiting students. But, as I pointed out, the image presented by the power supply authorities does not really encourage students to enter their industry.

The future

Because of international standards and rapid technological development, the course in electrical engineering must continue to move forward. I look for your support in this. It is essential, however, at the same time, that you review very seriously the methods which you adopt in training graduates. It is here that the recommendations of the Bosworth Committee are relevant to New Zealand. Although these recommendations were primarily for the manufacturing industries, they are so worded to meet the requirements of almost any industry, including that of the power supply industry. As engineers, we know what is meant by "matching", but if you consider the graduate leaving university and entering industry, there is a marked discontinuity between his studies and what he is expected to do on taking up an appointment. There should not be this marked discontinuity.

At the university we will be giving each student a project; he will have some practical work, and will apply his academic knowledge. Entering industry he should be allowed to continue to exercise his mind, at least, he should be guided into the type of work you expect of him and this is not "dig holes for poles".

At this point I think it is useful to consider the definition of an "engineer-technician".[1]

"An engineering technician is one who can apply, in a responsible manner, proven techniques which are commonly understood by those who are expert in a branch of engineering, or those techniques specially prescribed by professional engineers. Under general professional engineering direction, or following established engineering techniques, he is capable of carrying out duties which may be found among the list of examples set out below.

"In carrying out many of these duties competent supervision of the work of skilled craftsmen will be necessary. The techniques employed demand acquired experience and knowledge of a particular branch of engineering, combined with the ability to work out the details of a task in the light of well established practice. An engineering technician requires an education and training sufficient to enable him to understand the reasons for and the purpose of the operations for which he is responsible.

"The following duties are typical of those carried out by engineering technicians: Working on design and development of engineering plant and structures, erecting and commissioning of engineering equipment and structures, engineering drawing, estimating and testing engineering construction and equipment, use of surveying instruments, operating, maintaining, repairing engineering machinery, plant and engineering services and locating defects therein; activities connected with research, development, testing of materials and components, and sales engineering, servicing equipment and advising consumers."

Would it be true to say that many of the so-called professional engineers in small power supply authorities are in fact engineering technicians? Would it be true to say that a young man who has obtained the New Zealand Certificate in Engineering would be more fitted to carry out many of the tasks expected of many professional engineers employed by supply authorities? If this is so, then you undoubtedly treat the graduate engineer incorrectly. You do not give him the right induction training and in fact you probably look for too many. Is there in fact a job available for the graduate engineer? In many of the supply authorities I don't think there is. At the same time, however, the small supply authorities require the services of a professional engineer in order that they may plan their future plant. How then do they resolve this conflict between the day-to-day working of the industry and the requirements for professional services? I see only one way—there should be centres where groups of professional engineers with up-to-date facilities, including computer services, work together to advise the smaller authorities on the plant and methods of running plant. These centres would also provide the means for training the young graduate. When the graduate sees the opportunities that this could offer, I am sure that he would be much more encouraged to join the industry.

I am not here specifically advocating the amalgamation of all the power supply authorities into, for example, large area authorities. If this is the way to improve the services, make them more efficient, then I think it should be done; but I am concerned at present only with the supply and training of the professional engineer. The professional engineer must also start and exert much more influence within the various authorities. The influence at present does seem to be rather weak in many areas, but it is only the engineer who will make the change. A person, highly orientated technically, may not do this. It is therefore the duty of the authorities to ensure that a young graduate, who does undoubtedly think only of his technical ability, is shown how interesting administration and management posts can be. He should therefore spend some time with management.

I would like to end on this theme. A graduate entering industry is enthusiastic, you must maintain this enthusiasm. At no time must you allow his training to become boring; at no time must you expect him to do tasks which are clearly seen to be irrelevant to the job that he will have to do in the future. Remember that he is highly intelligent, he does not need to do the things a craftsman does in order that he may understand how a craftsman works. He can see this for himself. In any case, he has had up to nine months' industrial training and is already familiar with the situation. One of the most important things you should do is give a graduate responsibility, immediate responsibility, and if at first he is unsuccessful in carrying out his task, show him where he is wrong and give him guidance. Don't ignore him and, above all, be progressive yourselves. We must work together in this.

[1] The Institution of Electrical Engineers (1960): The Professional Engineer—The Training of Graduates.

Discussion

S. E. SLATTER (Central Canterbury E.P.B.)—I wish to thank Professor Kay for his address today. Our conference has now been privileged to hear the two professors associated with the training of electrical engineers. It is pleasing to note that Professor Kay has presented a new approach to the training of young engineers at his University. Professor Bogle has also advised that various changes have been approved, which in effect from 1967, increase the electrical content of the B.E. electrical course at the University of Auckland. In the final year, students may now present themselves for Electrical Design, Electrical Engineering, Industrial Administration, and two subjects chosen from Communications, Control Systems, Electrical Supply, Electromagnetic Fields, Engineering Mathematics and Industrial Engineering. We now hear that the prescriptions for electrical subjects are similarly under review in Canterbury.

At the outset it must be admitted that it is the undoubted prerogative of University to train young men to the highest possible level, and I for one would not suggest that the University should lower its sights purely to train persons for any of the specific disciplines within the electrical sphere.

It is apparent that Professor Kay looks upon training as embracing heavy-current and light-current engineering, with no particular bias. The points which I feel have been fundamentally at issue are the supply authorities' apprehension in being unable to recruit young men of the requisite calibre, and the opinion of the universities that the training of engineers outside the universities and large Government establishments is open to question, and also that supply authority engineering offers little to those who aspire to careers which challenge their technical ability.

I think that it would be true to say that in the past the supply authorities have shown no real desire in interesting University professional staff in the distribution side of the industry and equally I feel the universities have broadly directed their graduates towards the more glamorous disciplines in which research into control, communications and aero space is the firm objective. However, as the Christchurch city engineer (P. G. Scoular) has recently stated:

"Graduates from universities never were engineers", and

"Engineers are not trained to be contractors, nor are they trained to be consultants, nor local body employees, government employees or anything else. They are simply taught the basic sciences of engineering, and any employer must train them for his business. Municipalities have to give them just as much training as contractors do."

However, I do not feel that it is "unfortunate but inevitable that the training in universities today is invariably becoming more academic and less practical."

A new course will begin next year at the University of Canterbury designed primarily for people with suitable qualifications. Industrial and advanced training will be offered in the modern technologies of electrical and electronic engineering. This type of course follows those which have already been established for some years in the United Kingdom and the United States. The training will consist of about 200 lectures on electrotechnics, computers, electromagnetics, along with suitable laboratory work and research. It is the University's aim that this course will provide a further link between it and industry.

Notes recently produced by the chairman of the Education Committee of the N.Z. Institution of Engineers have a very interesting comment on non-technological subjects. Again I quote:

"Institutions in the U.S.A. require that universities include in their engineering degree courses some 20% of time spent on non-technological topics. How much substance is there in the criticism that New Zealand engineers are hardly literate?"

I feel that a formal base-course should be devoted to the humanities, cultural studies and management techniques generally. This type of broad-base education is more typical of university practice overseas and I feel that such an approach could be examined with profit in this country.

However, I am firmly of the opinion that the university course should not be lowered to provide more recruits for any individual industry, I feel that this is more the task of colleges related to technology, at least in the initial stages. That such a college may eventually aspire to university status is another question.

The establishment of nuclear stations in this country in the near future will, of necessity, require staff of the highest calibre. Graduates in this field must be recruited from the disciplines of nuclear physics and electrical engineering, and it has been stated that to ensure people of the necessary calibre come forward, provision should be made for creative research. Therein lies the rub in so far as high level education is concerned. A recent editorial in the *Christchurch Star* said:

"Universities are not designed as night schools . . . While there is a recognised need for accelerating technical education in this country there is also a parallel need for encouraging the development of science and research."

Thus we have two apparent needs:

(1) The training of a sufficient number of suitable technicians and so-called stereotyped professionals; and

(2) The encouragement and development of pure science and research.

I suggest that our industry should re-examine the situation regarding the employment of young graduate engineers within its ranks, as I am quite sure that we can provide a suitable climate for these young men. I should like to quote some questions which were discussed at a conference in New Hampshire (U.S.A.). Key questions examined included:

What do young engineers expect from their work? What are some of their career problems, and what can they do about them? What might management do? Why do so many engineers strive for management positions?

These aspects were studied by representatives from manufacturing companies, public utilities, engineering schools, professional societies, and engineering publications. The degree to which a young engineer feels frustrated or warm towards his job, the conference reported, depends on the extent to which his expectations have been matched by employment realities, whether his expectations are to receive meaningful realisation where he can use background education and experience, display talents, be given responsibilities, associate with accomplished engineers, acquire further education and experience and receive recognition for accomplishments, including salary increases, promotion and personal acknowledgment.

It would be quite true to say that young people are drawn to where the action is, and that they want important work, challenging job opportunities, and above all, work that will give them a sense of achievement.

Dr George Hawkins, Dean of Purdue University Engineering School, has said that for some engineers technical obso-

lescence begins the day they pick up their diplomas, as they have somehow failed to learn that education is a life-long self-imposed discipline, and eventually they will blame the universities for their educational shortcomings. Dr Hawkins talks of the four ages of the engineer and they are worth quoting:

(1) The recent graduate is impatient because he cannot cope with practical problems as easily as does the old engineer. He wishes that he could have had more practical courses in his study programme.

(2) Approximately 10 years after graduation the engineer complains he should have had more mathematics and physics, chemistry and engineering science to solve the difficult contemporary problems in engineering.

(3) Approximately 15-20 years after graduation he voices a need for more courses in management administration as he needs the skills in public speaking, writing, labour relations, finance and budget control, and he has at last learnt that technical confidence alone is no guarantee of success in personnel and administrative matters.

(4) Twenty-five years after graduation and beyond, the engineer reflects that a greater number of college courses should have been devoted to the fine arts, music, literature and drama, as he feels deficient in these areas when talking with contemporaries and, as Dr Hawkins observes, the fully matured engineer feels slightly uneasy about his neglect of the cultural pursuits.

These then are the four ages of the working engineer, and each requires a specialist knowledge and skill. It is quite apparent that we cannot ask our engineering schools, within the universities, to prepare the graduates for every technical and social situation that they are likely to encounter in their working lifetime. It would appear that the title of Professor Kay's address is very apt. We in industry, or in public service, must understand the universities' point of view and I feel that we should make the universities aware of both our shortcomings and our attributes.

In the light of the tremendous growth in our industry and in its future requirements for professional staff to carry out its programme in a competent manner, I feel that his heading is indeed apt—"Divided we Fall".

G. H. Battersby (consultant, Christchurch)—Unfortunately the University of Canterbury cannot talk too widely about itself, because universities do not advertise their wares except by example. It is most unfortunate, as Mr Slatter has said, that we get the idea that the progress of science begins to end the day we leave the university, but that is a most mistaken idea, and to assist those of us who are misguided that way, the University of Canterbury is putting on a course under Professor Kay which opens next year especially for those who are engaged in industry. The object of the course is to bring industry and the university closer together and this is a course leading to an M.E. degree or an equivalent qualification. It will be a refresher course and will explain developments and scientific aspects of engineering which have taken place since the grown-up man in industry at present, finished his university studies. This course would be eminently suitable for those who feel the need for that and I am only sorry that there was no such course available 25 or 30 years ago when it might have been of some use to me. The University will be glad to supply you with details on application, but unfortunately it is not the sort of thing that can be advertised except in their Calendar.

E. B. Mackenzie (N.Z. Electricity Department)—Some four years ago I was told by Professor's Kay's predecessor that the Government was at the bottom of the list of preferences for students leaving the University. Since then we have done a lot of soul-searching to the extent that this year we are hoping to recruit about 20 or so who will be trained to quite a good standard for the New Zealand Certificate of Engineering. We hope to build that up to the stage where over the next seven, eight or 10 years the N.Z. Electricity Department will probably be allocating three holders of the New Zealand Certificate of Engineering to each professional engineer employed by us. That is a starting point.

When visiting the United Kingdom, at the request of the N.Z. Institution of Engineers I was asked to have discussions with the Institute of Electrical Engineers on membership standards, and it was quite clear that they would recognise for corporate membership only the chief engineers of about 10 of the larger supply authorities. Anyone below that would have a very lean time. I did my best to persuade them, but that illustrates their approach to the supply authority engineer.

We are trying to improve our relations with the University and over the last two or three years we have been able to work closely with it on one or two projects. We have not done as much as we would like, but we have done one particular job which we could not have done without a lot of help from the University of Canterbury's Engineering School. The work that we have done led us to think that we should encourage graduates to go back to university after three years or so in the N.Z. Electricity Department, possibly with the idea of obtaining a Ph.D. This is quite a revolutionary idea. It would involve paying the graduate his full salary for the three-year period, and we could not afford to send one every year because that would mean that we would have too many staff away, but we hope to appoint the first one for the next University session—one graduate who will go back for a three-year course to take his Ph.D. The appointment would be known as the N.Z. E.D. Power Fellowship and the person taking it will be known as an N.Z.E.D. Fellow. He will attend the University for three years, working on work associated with the activities of the N.Z. Electricity Department and leave, we hope, with a Ph.D. After the second year of that appointment, we will appoint another one so that every other year we will have two at the University, and during each intermediate year there will be one. They will take up their appointments a Fellows probably three years or so after leaving University.

Twenty years ago all our graduates were electrical engineering graduates, probably in 10 years 40% will be electrical engineering graduates and 60% will have a mechanical background.

M. G. Keys (Auckland E.P.B.)—In our experience graduate engineers very quickly find themselves having to think in terms other than purely technical ones. They come up against the economics of the industry and the accounting side. This is a field in which engineering graduates, in general, have no knowledge or experience. Although it is obviously very difficult to introduce "outside" subjects in an engineering degree, where the technical side is so rapidly expanding and becoming more and more difficult to follow, it does become equally difficult for the graduate engineer to find himself suddenly faced with purely accounting work quite quickly after his graduation, and be unable to cope with it.

R. W. Hubbard (Waitemata E.P.B.)—What is the professor's attitude towards those students who come to us in the supply authority industry, study for their Certificate of Engineering, pass it, and would then like to have this qualification recorded—from the point of view of going on to University and taking the B.E. degree course? In Auckland this is not looked upon with very great favour, and it would be interesting to have Professor Kay's opinion on the degree of recognition in this context that the Certificate of Engineering should be accorded.

Author's Reply

PROFESSOR L. KAY—When I agreed to speak I was a little apprehensive about how I might be received and I am relieved to have been received so well.

I cannot agree that engineering graduates do not become engineers. I call myself an engineer and try to do practical things. Some graduates do not become engineers but this is not necessarily the fault of the graduate or the profession. Some just have a change in outlook. I would hope that the majority who graduate in engineering become engineers, although the definition may vary —people have different ideas about what is meant by "engineer".

It was interesting to hear the comment on the broader education of graduates in the U.S.A. In fact in the United Kingdom three hours per week, in all three years, is taken up with general studies in many universities. I am introducing "General Studies" into the final year at Canterbury. This has not been done before, to my knowledge, and I therefore thought it would be rash to introduce it into the three years at once, so I am trying the final year first. I would like industry (and again I refer to industry as those places outside University and Government Research establishments) to express its views on what is necessary for the broader education of engineers. It is one thing to lead a horse to water and another to make it drink; the student's views must be taken into account. It is no good attempting to give a graduate a broader education if he is not interested.

The power systems course will include nuclear engineering because power engineers will need to know something about this. The communications engineers will not study nuclear engineering as a specific subject. The Engineering School has a teaching reactor—the only one in the country—and we are using it as effectively as we can.

The question of economics is a difficult one. We know that many engineers become involved in economics and certainly, in their later years, they will be more involved than at the beginning of their careers. If a graduate is well trained and has an active mind, it is surprising how quickly he can pick up the essentials of another discipline, but if he had some basis on which to build it would be much easier. "General Studies" may include economics for this reason. It could include industrial psychology. Which of these would you choose? If you can imagine all those things that you think we should teach an engineer in order to broaden his outlook and to help him understand his society, and you remember that we have only three hours per week in which to do it, you will begin to understand our problem.

Finally, the New Zealand Certificate of Engineering—I was very pleased when I came to New Zealand to find that this certificate was growing in stature. In the United Kingdom, as you are all aware, there is a comparable certificate which has been going on for many years—the Higher National Certificate. This is now dying out because so many young people go through grammar school and obtain "A" level certificates, which are equivalent to a scholarship in New Zealand. After that, they can go to university and enter at 1st professional year or take a fulltime course of 18 months for a Higher National Diploma. The Higher National Certificate was always though of highly, particularly in the supply industry. When I was with the supply industry almost all district engineers had Higher National Certificates and were eligible to become corporate members of the Institute of Electrical Engineers. Few had degrees. Lately the swing has been to Higher National Diplomas, although more graduates are becoming district engineers. I do not think that the N.Z.C.E. quite measures up to the H.N.C., but I have a higher opinion of it now than I had when I first came to New Zealand.

I have visited the technical institutes and have talked with the principals and heads of departments concerned; they have a very strong interest in developing the Certificate and the courses. They are capable of doing this, and should be encouraged, because it is from those people who obtain the N.Z.C.E. that we are going to find our technicians of the future. As Mr Mackenzie says, we need at least three to every graduate engineer, otherwise what is the engineering graduate going to do?—the technicians job! There must be a bridge for those young people who by chance have taken the wrong path, and at a later stage want to go to university. We would like to give them that chance, but expect only a few to qualify. We have to assess their ability, determine whether they are capable of sustaining a high standard of academic work for two or three years, and we need to be sure that they have mathematical ability.

Address by A. W. Gooder, J.P.

(President, Electrical Supply Authorities Association)

General

AS some of you know, I have been endeavouring to inculcate a team spirit in our activities. At times, perhaps, I have not made my aims clear. I regard the Electrical Supply Authorities' Association as the central umbrella of our industry's activities, with a wide variety of activities being sheltered under that umbrella. As an industry we are not just a collection of parts, we are sections of a whole and therein lies our strength.

At times in Association affairs it is difficult to be sure which section should deal with a particular subject. Policy recommendations very often depend almost entirely on the advice we receive from officers in the industry. Electricity promotion is probably an Electrical Development Association item. Staff matters may be of prime concern to our Union. But all of these matters are so intertwined that they are industry matters and, for our own good, we must work together as a team.

Earlier this year I explained to your presidents and vice-presidents how keen I was that all our activities should not be kept in separate watertight compartments. Even on confidential matters I see only good coming from a continuing flow of information among our own people. I was not envisaging any complicated form of reporting, merely a steady interchange of information. There are few things in our industry which are particularly confidential and some of the confidential things are unnecessarily so in my opinion.

The work of our Association requires the cooperation of all branches of the organisation. We are all working for the one purpose. When I refer to the Association I mean the industry as an entirety, working to safeguard the rights of the member authorities and through them, the consumers of electricity.

Import licensing

With the serious need to conserve the country's overseas funds, our industry has naturally been under some pressure so far as imports have been concerned. Our long-term objective is that material used for electricity reticulation purposes should be freed from import licensing control. Such material is required to give service to our consumers and, by regulation, we are required to give a supply to all who ask for it and to give a supply within certain strict limitations. We do not seek to import material for the purpose of making a profit.

In recent years supply authorities have cut their requirements to the bone, and we are swiftly reaching the position where it is quite impossible to make any further cuts or savings. Unless our industry receives licences to import this essential material, there is every possibility that electric supply will not be available to all who want it or that regulation voltages will not be maintained.

The Association maintains a very close liaison with the officers of the Department of Industries & Commerce and this liaison has proved to be beneficial to members. Many of you will know that a phone call or a letter to the Association office has resulted in the clearing of an apparent bottleneck.

As a result of very recent discussions, we are now in the process of preparing some comprehensive information for you which I am sure will make future dealings on the subject smoother than in the past. We have been very fortunate in securing the services of two senior officers to help with this work. J. K. Hooker, the recently retired general manager of the Wellington M.E.D., and G. Rowbottom, recently retired stores controller of the Auckland E.P.B., are cooperating with our office in producing what could be described as an encyclopaedia on the subject. With the assistance of the Department of Industries & Commerce, this could result in the clearing of bottlenecks and, in fact, the prevention of bottlenecks.

It seems likely that our Import Licensing Committee will have an increased programme in the months ahead, but if this results in smoother licensing it will be time well spent. I will be asking each authority to keep the Association office fully acquainted with any problems, because these problems are often mutual ones. When a problem is solved for one authority it very often solves it for everyone else.

I want to say how impressed I have been by your answer to my appeal earlier this year to conserve funds in the interests of the country's economic position. You have acted in a responsible manner which has made negotiations on behalf of the industry very much easier.

Savings through cooperation

As the result of an extensive investigation by officers in our industry, the Association was advised that there were little or no monetary savings to be made by any schemes of bulk buying. We were told, however, that there is scope for financial gain by a rationalisation of the material we buy. In other words, we stand to gain if the industry buys only seven variants of a product instead of seventy.

This is something which is in our own hands. Today is a time of standardisation, but in an industry like ours where characteristics must be variable, I prefer to use the word rationalisation, in the sense of being sane and moderate.

We cannot expect spectacular results in a matter of weeks. This must be a gradual process spread over a long period. It cannot hope to succeed unless it has the support and cooperation of everyone in our industry. Many things which we purchase are peculiar to our industry; it is in these items where a rationalising movement must eventually result in savings.

In this past year we have made a start with distribution transformers and I must admit that progress has been slower than I had hoped. However, in commerce there are two parties—the seller and the purchaser. In the coming year the purchasers may have to apply a little pressure.

This idea of rationalisation can be applied to the small items as well as the large. One authority may be paying more than it should because it is buying a crossarm brace which is a non-standard thickness. I feel that many of our troubles in this field—and in others—can be put down to lack of liaison between authorities.

Now that we have located the trouble, let us cure it.

Electricity tariffs

During the past year or two we have probably paid more attention to electricity tariffs than we have over many years. Everything has not gone our way, but it is certain that we have learned a lot and that we still have much to learn.

The Association has constituted a Tariff Research Committee with two main objects—first, to watch the effects of the new bulk-supply tariff and, second, to examine the field of retail tariffs. The speaker to your combined conference this morning is a member of that committee and it is obvious that he has been doing his homework.

I feel certain that this committee has an invaluable part to play in our industry, but tariff research is not something which should be confined to a few. All of you would wish to be better informed on this most important subject.

Some of you took part in meetings during this past year which were virtually study groups for small numbers of executive officers. From the reports I have heard, these meetings were very successful, but it would be true to say that they merely scratched the surface. However, the aim is an excellent one and I trust that in the year ahead you will ask the Association secretary-manager to arrange more of these meetings in your area.

The Critical Path Method

F. P-S. LU, B.Sc.(Eng.), M.N.Z.I.E.
(Senior Lecturer in Civil Engineering,
University of Canterbury)

THE Critical Path Method (c.p.m.) is a tool of management and a tool which is based on experience and commonsense. One of the things it does is to put commonsense and experience on paper so that others, less gifted, including your juniors and subordinates, can make use of your commonsense and your experience to guide and help them.

There is no magic about c.p.m.; it only puts down on paper your commonsense, your experience. In doing so it follows a certain methodology and that is something on which I have a few words to say.

Primarily it is a method of planning, and as a method of planning it is no different from other methods of planning. Its first step is to break down a particular project into its component operations. We all know from experience and commonsense that all of these operations are not the same: some are critical and must be completed in time in order to finish the project on time. There are many others that are not critical and which can tolerate a certain amount of delay without affecting the project completion.

What the c.p.m. does is to pinpoint all the critical operations in advance—at the beginning of the project—and at the same time define the non-critical operations. The critical path is simply a connected sequence of the critical operations. If you join all the critical operations together to form a continuous path you have this so-called critical path. The method also finds out the degree of non-criticality of the non-critical operations. (If you take too long to do a so-called non-critical operation it will also become critical.)

It is therefore important to know how much spare time, or "float" you have for the non-critical operations.

To put down your commonsense on paper, we use a technique of graphical representation of words. All operations, physical or non-physical, are represented by arrows. The tail of an arrow marks the start of the operation it represents, and the head its finish. The start and finish of operations are called "events". For clarity small circles are drawn at the tails and heads of arrows to denote events. The arrow diagram is drawn by joining the events together to show the correct and logical sequence of operations. The arrows are initially not drawn to scale and their lengths are at this stage unimportant. Their directions show the flow of work.

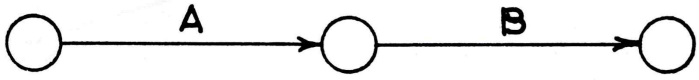


Fig. 1

Figure 1 shows two sequential operations indicating that Operation B cannot be started until Operation A is completed.

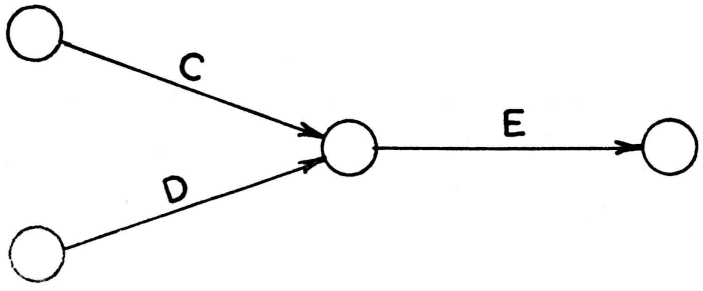


Fig. 2

Figure 2 shows that Operation E must await the completion of both operations C and D before it can commence.

Figure 3 (overleaf) shows that Operations G and H are concurrent operations which can be started when Operation F has been completed.

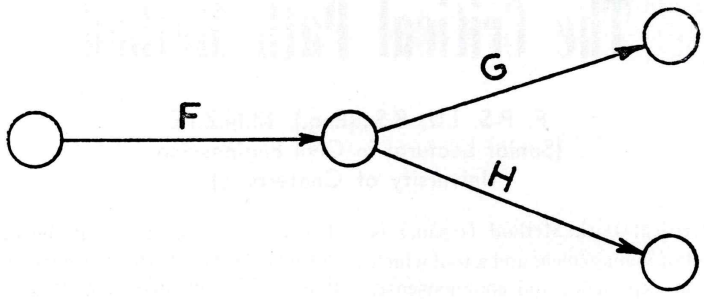


Fig. 3

When developing the arrow diagram, in order to ensure its logical sequence, three questions are asked of each operation. First: What must precede a particular operation?; second: What can follow it?; third: What can be done concurrent with that operation?

Those are simple questions, but extremely important.

All events are numbered to facilitate identification. This step is usually carried out after the whole arrow diagram is drawn. Each operation is identified by two event numbers, the (i) number at the tail of the arrow and the (j) number at the head of the arrow. For example, in Fig. 4 Operation C is identified by (1, 2) D by 2, 3) and E by (2, 4). It will be noted that for sequential operations, as C and D, the (j) number of the preceding operation is the same as the (i) number of the following operation. It will also be noted that concurrent operations, as D and E, share a common (i) number.

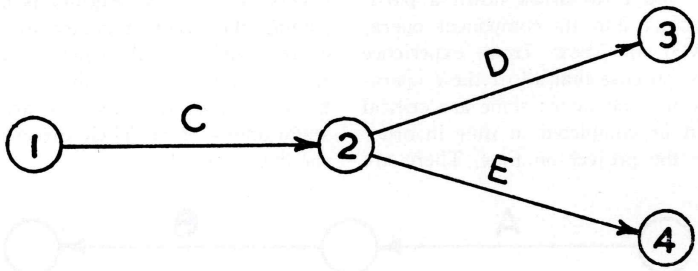


Fig. 4

The best way to illustrate this is by means of an actual example such as the commissioning of a major substation.

Usually the first step is to list all the operations necessary in order to commission a major substation and then join those operations together in a logical sequence to form an arrow diagram. When one is experienced, he can combine the two steps together (see Fig. 5).

This is the planning stage and fairly straightforward, and as can be seen is based on experience and commonsense.

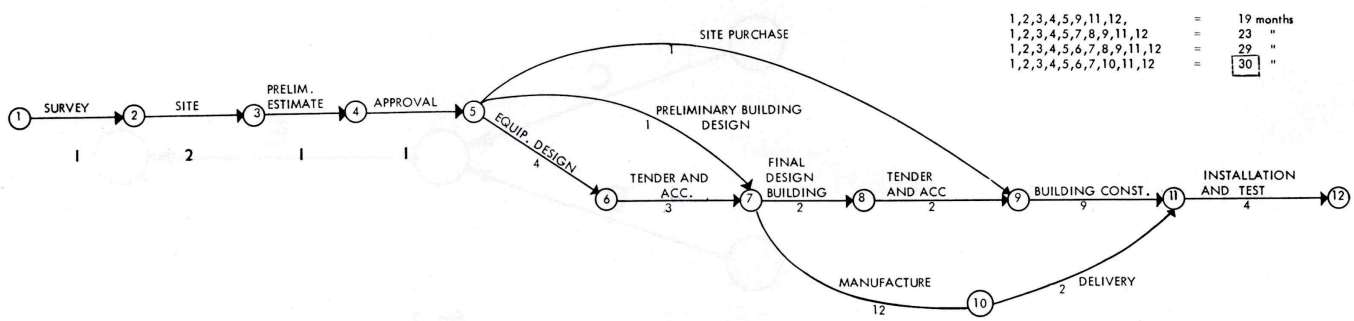
We can now go ahead with the next stage of the application of c.p.m., scheduling. We were concerned only with the sequence of the work, not how long the many operations would take, but now we are concerned with the time element and before we do that we must first decide on a unit of time—months, weeks, days, hours or minutes. This is a matter of convenience for a particular organisation and we choose for this exercise the working month as a unit. These times are added beneath the arrows.

The critical path is simply a connected sequence of all the critical operations and it is a connected path from the beginning of the project to its end, a path which will take the longest time to complete, not the shortest. We can locate the critical path by three different methods.

First is by trial and error. Add up the number of months required for the various possible paths and find the critical path.

Secondly, you can do a computation, or thirdly, you can go to the computer and after feeding in the necessary information the computer will locate the critical path.

In the first method, by trial and error, all we have to do is add up the total number of months along all the possible paths, and in the example we have 19 months—the second possible path adds up to 23 months; the third to 29 months and the fourth to 30 months. We have located the critical path, the longest path,



CASE 1. Project begins : 1 October, 1967. Completion reg'd 1 April, 1970 (30 months)

CASE 2. Project begins : 1 April, 1968. Completion reg'd 1 April, 1970 (24 months)
Expedtting reg'd Anticipate approval and start equipment design after survey.
Reduce installation and test by 1-month.
Reduce equipment design by 1 month.

CASE 3. Project begins : 1 April, 1968. Completion reg'd 1 April, 1971 (36 months)
A. Start early - make sure plenty of time - nothing critical.
(1) Drag out work to fill time.
(2) Normal work rate finish job 6 months ahead of requirements.
B. Lead time 6 months, finish project in 30 months. No float - 5 months lead time = 1 month float at end.

Fig. 5

and all the operations along this critical path are critical operations for which there is no spare time in order to finish the project in 30 months, and the other paths are non-critical paths, and operations along them will contain "floats" which have yet to be computed.

The critical path can be quickly located by trial and error for projects with, say, 100 operations but with a project approaching one thousand operations or more, it would be too time-consuming, and one needs a routine scientific method, by computations. The method is very simple and straightforward and may be assimilated from books.*

The third method is by computer.

Now take the method one stage further and see how to make use of this for actual project execution.

Case No. 1: If the 30 months are acceptable, and if the starting date of this project was 1 October, the 30 months would take us to 31 March 1970 or 1 April 1970. This is fine for this particular project—it would be ready to handle the 1970 winter load.

The use "site purchase" has 11 months float, so that if you can get the owner to leave the payment until after the end of the 11 months, this would be an intelligent use of the "float"—to save interest, etc.

"Building contract" has a total float of one month. You would be wise to keep this. (As long as the delay does not exceed the float of one month, the project will not be upset.)

Case No. 2: Supposing the starting date is now 1 April 1968, it is no use getting a substation completed in the summer months. It has to meet the next winter load so it might be better to put it off for another year. On the other hand, if April 1968 is the starting date, and you are anxious to have the substation finished to meet the winter load of 1970, the job completion time has to be cut down from 30 to 24 months. How can we do this?

Look for the long critical operations because they will save you the most time. It is obvious that it is no good at all to put the pressure on the non-critical operations. You must save the time on the critical operations. We cannot do much with the manufacturers overseas. If we could anticipate approval we can start the operation of "equipment design", not after approval, but as soon as the market or demand survey was done. That is a net saving of four months. The other two months could perhaps be saved by talking to the designers and saving a month there, and then asking the installation and testing people to do their work in three months instead of four.

This is the sort of thing which is possible through this method and this is something which you consciously or unconsciously do all the time.

Case No. 3: What happens if instead of the substation being required for the winter load 1970, it is required for winter load 1971—36 months, not 24 months nor 30 months. We start in April 1968 but we do not need it until April 1971. You could drag out all the operations to fill in the time. The other way of trying to fill out the 36 months' time schedule is to adopt a fairly prevalent attitude. This is to have everything non-critical so one has plenty of time. We still start on 1 April 1968 and if everything goes according to schedule we may finish six months early in the summer of 1967 rather than winter of 1968. What does that mean? Finishing six months early certainly means the consumers will get their power when wanted, but who is paying for the early finish? It would mean six months of cold storage for the substation, but the money has been paid out. A more intelligent approach is to accept the 30 months plan as reasonable and to have a lead time of six months which gives us no float, or split the six months to a lead time of four or five months, and a float at the end of one or two months.

All I have told you, apart from this very logical way of graphically showing everything in a diagram, is just commonsense and experience, expressed on paper. Admittedly the technique is somewhat different, but its basis is your experience and commonsense. Because of this, this wonderful and powerful tool of management may appeal to you more than perhaps to those with less experience and commonsense.

* Lu, F. P-S. (1964): The Critical Path Method of Construction Management (Caxton).

Discussion

R. W. Hubbard (Waitemata E.P.B.) asked a question regarding steps to be taken in turning a non-critical path into a critical path, and Mr Lu replied by illustrating his answer on the diagram.

D. H. Davidson (Hawke's Bay E.P.B.) asked how two separate operations which started with the same *i* number and ended with the same *i* number—operations which had to start together and finish together—would be shown and Mr Lu replied that a dummy operation would have to be introduced which would separate the two operations.

M. G. Keys (Auckland E.P.B.): in thanking Mr Lu said that no member would enter into an engineering project without taking out some figures and dates and times along the lines Mr Lu had put forward. This was essential for ordering material and making a start in planning.

Invariably a schedule was drawn up giving a picture of what was required, and when it was required. A development of this sort of procedure had been put before members by Mr Lu, based on a much more scientific basis. Instead of having a general picture and possibly having to decide when to introduce a "crash" programme, the method put forward by Mr Lu specifically set out the operations and one was able to see whether a particular operation would meet the dates set down for it or whether some crash programme would have to be introduced. All engineers were doing the sort of things referred to, but they would find an advantage in introducing a modest scheme in the form set out. The introduction of a critical path method would be essential for major projects such as a big bridge-building job, and for a substation project, the scheme outlined by Mr Lu could be quite adequate for general purposes and could well be introduced.

Mr Keys referred to a film he had seen on the subject, obtainable from the British High Commission library. The film was well worth seeing and would remind members of the various steps to be taken.

Tariff Framing

T. E. KELLY, B.Sc., C.Eng., M.I.E.E., M.N.Z.I.E.

(Chief engineer, Hawke's Bay E.P.B.)

The great variety of retail electricity tariffs throughout New Zealand is quite startling. It could be expected from the close liaison that exists between the officers of electrical distributing authorities that there would be a great similarity between areas, particularly with authorities of similar size, with relatively the same financial arrangements and alike in their establishments. Although independent thinking is to be applauded, a greater degree of tariff uniformity is desirable and would improve our public relations. Are the differences necessary? If not, can they be removed?

1. INTRODUCTION

MOST tariffs have persisted, in form at any rate, unchanged from the establishment of the organisation and date from a period when it was customary to frame the charge for electric power according to the use to which it was put. Thus it was common practice to charge a special rate for lighting, another for heating and another for motors.

More recently many of these tariffs have been simplified by amalgamating such separate-purpose rates into one composite one. Again, some authorities have also made attempts to rationalise charging according to the demands particular classes make on electricity at maximum loading times. In spite of these changes, no true uniformity has so far been achieved.

Basically, a tariff must be so framed that it will cover all the costs of supply. In addition it must be fair and equitable to all classes of consumers. A tariff can be designed for load promotion or to encourage a move of electricity load to more suitable times of the day. It can enable electricity to compete against other forms of energy. Above all, the tariff must be simple so that the consumer will have full knowledge of the value of his purchase and any alteration must be obviously fair if resentment is to be avoided.

2. TARIFF MAKING

Although electricity is in a predominant position in the economy of fuel in New Zealand we must never become complacent. Because of changes in the bulk-purchase tariff and the modern tendency to load, even overload, present revenue with current capital expenditure, the favourable margin in cost of electricity over other fuels is being eroded. It is vital to electrical authorities that they examine closely their tariff systems to achieve uniformity and design competitive tariffs that will appeal to the public.

Earlier tariffs seemed to be based on the manner in which electricity was used. For example, lighting was at a high cost and cooking at a lower cost. There are many relics of this era, particularly in non-domestic tariffs although most domestic tariffs are now one-rate tariffs covering all the various domestic uses.

Apart from simplification, the modern trend seems to be towards equating tariffs to the incidence of the various classes of loadings on the parts of the bulk-purchase tariffs and, by dividing a supply authority's costs into power and energy costs, to allocate these in a similar manner.

For those interested in this approach there is the following literature on the subject:

[1] FURNESS, R. F. (1962): "The investigation and derivation of an electricity tariff." E.S.A.E.I. *Transactions, 26.*

[2] —— (1966): "The selection of tariffs by electrical supply authorities." The Electricity Authority of New South Wales.

[3] FLETCHER, JOHN (1966): "Electricity tariff framing in an expanding system." World Power Conference paper.

[4] FALCK-JORGENSEN, SVERRE (1966): "Electric house-heating and its influence on total costs of supply." World Power Conference paper.

In spite of all the theoretical arguments for subdividing costs according to kilowatt demand and kilowatt-hour energy, and then allocating these costs in some proportion to the various classes of consumer, this whole system is founded on very insecure reasonings.

During the past year in discussions on bulk-purchase tariffs, quite eminent authorities have been at variance on the proper dividing of electricity costs and, except in the case of bulk supply, where continuous recordings of loadings are available, any attempt to allocate such derived costs to consumers can be done only by guesswork. To base any tariff on unproven assumptions does not lead to confidence, as the consumer is not in a position to understand and appreciate the several parts and refinements of this method of tariff framing.

A consumer can understand that if his supply of electricity is so controlled that it is not available to him at all times then that electricity should cost less than electricity which is freely available for normal use. But he cannot understand why the cost of "normal-use" power should vary between classes of consumers because of the amount of power a particular class theoretically uses at the authority's maximum loading period. This is particularly so if the consumer himself does not use power at that time.

For a long time consumers have been taught the value of a unit of electricity, how much light or how much heat it will provide, how long a motor will run and so on, to the stage that they understand that the unit of electricity is a unit of work and in their mind it should cost a certain definite sum.

It is true that the maximum demand of a supply authority in New Zealand is composed of contributions of load from the two main classes of consumers—domestic and non-domestic. It is true also that this maximum loading condition occurs in general between 5 p.m. and 6 p.m. in June and July. However, within these two consumer classes there are large groups who do not contribute significantly to this maximum demand. Families whose main meal is at midday and industries whose work stops at 5 p.m. or who have a predominate summer loading, are obviously not great contributors to the electricity peak.

If therefore it is desired to establish tariffs based on the maximum loading conditions of a supply authority, it is obvious that within the two principal classes of consumers there are large groups whose share of the maximum-demand purchase costs and supply authorities' costs are much less than the general body of similar consumers. These particular groups of consumers should thus have differing tariffs maintaining and extending the confusion that exists today as well as establishing unwelcome differences between consumers.

Creating tariffs to cover all such contingencies is unreasonable and is unnecessary if due attention is paid to the premise that the electrical unit is a unit of work and as such should cost the same for whatever purpose it is used. The electrical usage of all the various groups and classes of consumers makes up a complex which comprises the total loading of a supply authority and it is the diversity of all the individual loadings which enables generating and distributing authorities to sell economic electricity and utilise invested capital to the fullest advantage.

On these reasonings it is submitted that the basic price of all "normal-use" units should be the same and in what follows, this line of approach will be extended.

In total, the cost of electricity as it is sold retail to the consumer in New Zealand includes the following:

(1) Purchase costs from the N.Z. Electricity Department, composed of a maximum-demand charge and a unit charge.

(2) Capital charges relating to the supply authoritiy investment in distributing electricity from the purchase point to the retail consumer.

(3) Maintenance charges in maintaining the distributing assets.

(4) Management costs occasioned by the authority's operations.

(5) Surplus required both to stabilise the authority's annual accounting and to provide for some capital expenditure.

These may be proportioned approximately as in Fig. 1.

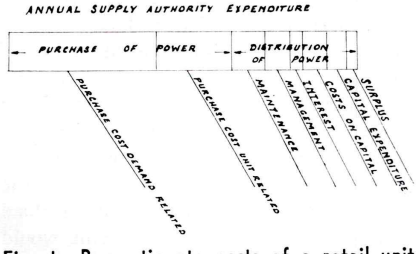


Fig. 1—Proportionate costs of a retail unit of electricity.

In the basic price of electric power in the various classes of tariff, variations can be introduced which have no association with the incidence of maximum demand but are closely related to the number of consumers in the electrical district.

3. CONSUMER-RELATED COSTS

In most tariffs in New Zealand, and also overseas, it is customary for the first few units sold to be at a higher price than the remainder. In some tariffs a basic charge is substituted for this block of units, but whatever method of tariff is used, this particular charge is sometimes known as an "availability" cost. Perhaps a more appropriate term is a "consumer-related cost" as it refers to the supply authority costs of operation which are related more closely to the number of consumers than to the quantity of electricity sold or the distribution of that electricity.

Part of this consumer-related cost should consist of the annual charges occasioned by investment in:

Service lines,
Meters,
Land for offices, stores and depots,
Instruments, and
Buildings, except substations.

The propriety of some of these costs being known as consumer-related costs is arguable, but they are more related to the number of consumers than to the quantity of electricity sold.

The annual charges on these items are, first, interest and, secondly, loan repayment or sinking fund and depreciation. To these particular costs an appropriate share of whatever surplus is required on the annual turnover could be added, but it is possibly more suitable to associate surplus with electricity sales as distinct from the number of consumers. The interest rate is that rate equivalent to total annual interest paid as a percentage of the capital invested. Similarly the other capital charges should be so computed. Only in this way can the true worth of these items be understood and the variations in interest rates be removed.

In addition some portion of the annual operating expenditure is fairly chargeable to consumers according to their numerical strength. This portion is contained in the management account, but engineering costs normally within that account are more directly concerned with power and energy sold, therefore, it is suggested that 60% of the annual management account be appropriated as a consumer-related cost.

All consumers can be divided into two main classes—domestic and non-domestic —and in proportioning the consumer-related costs there is reason to load the non-domestic consumer more than the domestic consumer. Generally the non-domestic consumer requires more sophisticated metering—he demands a higher standard of service and, owing to reticulation being underground in central city areas, his service costs are greater.

With these ideas in mind a double share of the consumer-related cost should be demanded of every non-domestic consumer. It is only fair to say, too, that the rural consumers' share should be very much greater than that of the normal urban domestic consumer, but as it is customary to use the same tariff for all consumers in the same class throughout a district, this extra charge, although quite proper, must be omitted.

The various parts of the consumer-related cost for domestic consumers are shown in Fig. 2.

Fig. 2—Consumer-related cost

4. RESTRICTED USE TARIFFS

The nature of the two-part purchase tariff employed by the State generating authority in selling electric power to the distributing authorities allows for a distinction in retail price between on-peak and off-peak unit sales. In making any distinction between supply under these headings it must be clearly understood that the distributing authority has complete control of the duration of off-peak supplies and the consumer therefore can use such electricity only for restricted purposes. It is proper, therefore, that the consumer should have a lower tariff for such restricted usages than he would have for normal-use electricity. Generally, a restricted-use consumer is also a normal-use consumer in the particular field of supply, either domestic or non-domestic, and he would therefore meet his consumer-related cost, but if this is not so then arrangements must be made to that end.

Restricted-use tariffs are valuable in providing a means for a consumer to reduce his overall fuel cost—with the provision that he accepts some restriction in service. Such tariffs are particularly attractive for any form of heating embodying storage or for processes that can conveniently be stopped for a period of time or that can properly be carried out during off-peak hours. Thus, these tariffs enable electricity to compete successfully against other forms of energy. As far as practicable, therefore, electricity sold under restricted-use conditions

should offer a good reduction in cost on normal-use electricity and undersell competing forms of energy by a reasonable margin.

Restricted-use units do not attract the maximum-demand purchase cost, but they are liable for the unit purchase cost of 0.27c plus losses which are most conveniently assessed at 10% so the first part of the unit cost is 0.297c.

In addition, there are costs peculiar to the distributing authority's workings. In their broad categories these costs are:

Management, excluding that portion already designated consumer-related cost;

Maintenance;

Annual capital costs, apart from those absorbed in the consumer-related cost including interest loan repayment, sinking fund, depreciation; and

Surplus, whether appropriated to capital works or general reserves.

It has been shown quite convincingly by various authors that these annual expenditures should be classified variously to maximum loading and to energy. It was said previously that cost allocation of this nature is unreliable through lack of precise knowledge and this is substantiated by the variety of methods used to determine the so-called division.

It can also be shown that the greatest utilisation of capital invested in reticulation often occurs when restricted-use power is available and not necessarily at the time of the overall system maximum. This is added reason for not subdividing supply authority costs on the basis of maximum loading.

Therefore, the most realistic, practical and certainly the simplest method of allocation is to divide all the supply authority costs, except those already set aside as consumer-related costs, equally among all retail units sold.

It will generally be found that the minimum selling price of restricted-use electricity is 0.65c to 0.75c per unit. If any greater return is desired this should contribute to the cheapening of normal-use units in the appropriate consumer class.

A restricted tariff as outlined can be available for 22 to 23 hours a day except under the most adverse weather conditions. There are, however, certain kinds of use when a much more restrictive supply would be quite acceptable, particularly during the night hours from 10 p.m. to 7 a.m. At this time the supply authority's system is operating well below capacity, and many authorities promote a special cheap tariff on the assumption that the units should not attract such a large share of the supply authority's costs, particularly those relating to capital.

It must be emphasised again that no consumer should be allowed to use only restricted-tariff electricity for any one service connection unless he contributes his full share of consumer-related costs at that connection. Figure 3 shows the composition of restricted-use unit costs.

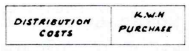


Fig. 3—Restricted-use supply—division of cost.

5. NORMAL-USE UNIT TARIFF

The basis of this appreciation of tariff framing is that all normal-use units, whether domestic or non-domestic, should have the same basic value. The steps to obtain this value are obvious: The maximum-demand purchase cost is divided by the total normal-use units sold, and to this unit cost must be added the unit purchase cost plus a percentage for losses and the supply authority's internal expenditure unit cost already determined. This is illustrated in Fig. 4 without consumer-related cost.

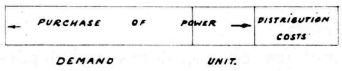


Fig. 4—Normal-use supply—division of cost

This is the common unit cost which is applicable to both normal-use tariffs—domestic and non-domestic. The unit cost in each class can be modified by any credits or debits that are available from other sections of the tariff peculiar to the particular class of consumer. For example, an authority may decide that a higher price should be charged for restricted-use units sold to domestic consumers than is strictly correct after all costs are considered. The credit for the sale of these units should obviously be applied toward reducing the unit price for normal-use units. Similarly, higher than calculated consumer-related cost would be used to cheapen the balance of that particular tariff.

The actual tariffs are then designed with the addition of the consumer related share of costs. It has become common practice with the domestic tariff to start the tariff with a basic charge—the consumer-related cost—or a block of high-priced units incorporating the same with all units thereafter at the one price.

On the other hand, non-domestic tariffs are generally of the stepped type. The first step includes the consumer-related cost, but subsequent steps are generally assumed to follow the business principle that quantity buying should be at a cheaper per-item-price than small purchases. An indiscriminate approach to this form of tariff results only in the small consumer paying for the concessions to the large user, but it is quite possible to develop a tariff of this type on a reasonable foundation.

The smaller non-domestic consumer is supplied from the normal low-voltage distribution so that the cost of his supply would include a share in all the distributing authority's costs, capital and otherwise. A larger consumer requiring 100 kW or more in power would probably be supplied directly from a transformer on his premises, therefore some capital costs can be reduced. No share of the 400 V reticulation is truly applicable.

It can be assumed that loads of this size can conveniently be supplied from the normal 11 kV distribution, but, for loads of, say, 3,000 kW and upward, it is probable that they would be situated very close to a district stepdown substation or be supplied at transmission voltage with an internal stepdown substation, thus reducing costs still further. The steps can be so adjusted to take advantage of the reduced capital in use in giving supply, but in compounding such tariffs one must be conscious of the average basic price already developed.

Finally, it is necessary to consider the large non-domestic consumer with a high load factor. A high annual load factor can be achieved only by a consumer who has a significant night and week-end load. Under the most optimum conditions of utilising electrical plant a consumer whose business is operative for a 40-hour week throughout the year cannot have an annual load factor greater than approximately 20%. In actual practice the annual load factor would seldom be better than 10-13% and therefore it is reasonable to assume that the extra units which would improve the load factor beyond 20% are those which could normally be considered as off-peak units. Thus the consumer should receive advantage for their use.

6. TWO-PART NON-DOMESTIC TARIFF

A Hopkinson-type tariff is admirably suited to give credit for off-peak usage to consumers whose business is operative round the clock and during weekends. This tariff can be designed to preserve proper payment for normal-use units as well as a reduced charge for those units used out of normal hours. The basic features would be that the average price per unit at 20% load factor would be the same as the average price for the non-domestic tariff and at 100% load factor the average price per unit would be equal to the off-peak tariff price plus

20% difference between the cost of normal-use units and off-peak units.

Provision for the consumer-related cost is generally accomplished by commencing with a high step in the kilowatt section of the tariff. Further steps in the kilowatt tariff will also provide for reducing the cost per unit according to the magnitude of the consumer's supply. This follows the same principles as are suggested for the normal non-domestic tariff, that is to say reductions in tariff according to the decrease in capital in use to provide supply. The change in cost per unit according to improving load factor is forcibly indicated in Fig. 5, in comparison with the average rate that would apply on the standard unit tariff.

7. CONCLUSION

This paper is written on the basis that normal-use electrical units should be equally priced both for domestic and non-domestic use. There are adjustments that can be made in both tariffs by a judicious pricing of the appropriate restricted-use tariff, and the non-domestic tariff can be stepped to accommodate relatively large consumers whose requirements for distribution capital are proportionally less than smaller consumers.

In New Zealand domestic tariffs have been developed so that they are cheaper than non-domestic tariffs. Although scientific investigations have purported to prove that this should be so, they are based on doubtful premises. Probably the most acceptable reason for cheaper domestic tariffs is that the domestic user is the end user of all electricity. In some form or another, all costs are eventually passed on to him through his purchases, taxes, rates, etc., and it is held to be just that any direct costs should therefore be kept as low as possible.

On the other hand, promotion of industry, particularly when there is a high electricity-cost content, often requires a low tariff. This is particularly so when there is competition with similar industries in other districts or other countries. The distributing authority in such cases must be fully aware that any reduction of revenue from one class, or even a particular consumer, must be compensated from other sources. The supply authority is therefore inclined to consider the benefits derived from ancillary business and additional population as being the compensating influence.

It is quite apparent that, after retail tariffs have been determined by a careful study of the expenditure incurred in the supply of electricity, they can and probably should be further adjusted for

(*Continued overleaf*)

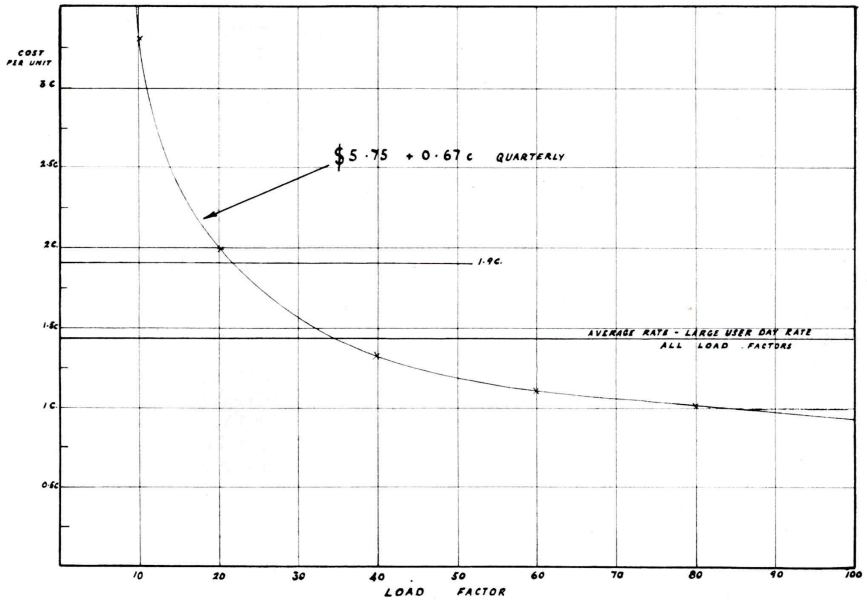


Fig. 5—How unit costs change with improved load factor.

APPENDIX—A SAMPLE TARIFF

Anticipated expenditure for year 1967/68

	$
Purchase of power demand charges	1,511,300
Purchase of power kWh cost	784,600
Authority's costs:	
Maintenance, including replacements	343,000
Management	259,700
Interest on current loans	130,000
Loan repayments (in lieu of sinking funds and depreciation)	258,000
Capital expenditure direct from revenue	216,000
Surplus	135,000
Total expenditure	$3,637,000

Tariff to return expenditure.

Calculation of consumer-related cost

Applicable capital

	$		$
Land	73,400	Proportionate interest, at 1.6% on $1,287,400	20,500
Instruments	35,400	Proportionate loan repayments at 3.2%	41,000
Furniture	96,000	60% management	156,000
Buildings	572,600		
Service lines	150,000		
Meters	360,000		
	$1,287,400		$217,500

Number of domestic consumers 26,200.
Number of non-domestic consumers 2,900.
On basis of non-domestic consumer rate being 2 × domestic-consumer rate.

Therefore, consumer-related cost, domestic	$ 6.8 per year
consumer-related cost, non-domestic	$13.6 per year
Actual costs fixed by authority, domestic	$ 6.0 per year
Actual costs fixed by authority, non-domestic	$30.0 per year
Therefore, amount to revenue account from domestic consumers	$157,200
amount to revenue account from non-domestic consumers	$ 87,000
Shortage transferred to normal-use domestic tariff	$ 20,960
Excess transferred to normal-use non-domestic tariff	$ 47,560

Calculation of restricted-use tariff

Kilowatt-hours purchased, 290.8×10^6
Kilowatt-hours losses, 26.5×10^6
Kilowatt-hours sold, 264.3×10^6

Authority's own internal costs	$1,341,700
Less appropriated consumer-related cost	$ 217,500
	$1,124,200

Therefore, cost per unit sold 0.4253c.
Therefore, cost of restricted-use units 0.4253c authority cost
0.27c purchase cost
0.027c loss cost

0.7223c

Authority's price for domestic units, 0.75c
Authority's price for non-domestic units, 0.80c
Domestic restricted-use units, 94.3×10^6 kWh
Non-domestic restricted-use unit, 2.0×10^6 kWh

	$
To revenue account from domestic restricted-use supply	707,250
To revenue account from non-domestic restricted-use supply	16,000
Excess transferred to normal-use domestic	26,121
Excess transferred to normal use non-domestic	1,554

Calculation of normal-use tariff

Normal-use units sold, domestic 89.6×10^6 kWh
non-domestic 78.4×10^6 kWh
Total 168.0×10^6 kWh

Of the non-domestic units 17.4×10^6 kWh are sold on a Hopkinson-type tariff. It is considered that half are actually restricted-use units for which the price is 0.8c/kWh.

	$
Therefore to revenue account	69,600
Excess to normal-use non-domestic tariff	6,760

Therefore, normal-use tariff units $= (168 - 8.7)\ 10^6$ kWh
$= 159.3 \times 10^6$ kWh
Demand charge power purchase = $1,511,300
Cost per unit = 0.9487c
Therefore, total mean cost normal-use supply:

Demand purchase cost	= 0.9487c
Unit purchase cost	= 0.27c
Loss cost	= 0.027c
Authority cost	= 0.4253c
∴ Mean cost	= 1.671c

Domestic normal-use units, 89.6×10^6 kWh
Shortage from domestic consumer-related cost = $20,960
Excess from domestic consumer restricted use = $26,121
Actual tariff by authority 1.425c kWh.
Shortage from true charge 1.671 — 1.425c kWh = 0.246c kWh

	$	$
To revenue account from normal-use domestic		1,276,800
Shortage to non-domestic normal use	220,316	
Less	5,161	
	$215,155	

Credit from consumer-related cost 47,560
Non-domestic normal-use units 69.7×10^6 kWh

	$
restricted-use tariff	1,554
Hopkinson tariff	6,760
	$56,874

To provide for lower domestic-use tariff, $215,155
Therefore, net extra required $159,281
which is 0.229c
Therefore, mean price normal-use tariff, 1.900c
To revenue account on this price $1,324,300.
The non-domestic tariff evolved is 7,000 kWh at 3c kWh/two months which the first 400 have an extra 1.25c per kWh consumer-related cost.
Over 7,000 kWh at 1.425c/kWh.

Revenue account

	$
Consumer-related cost, domestic	157,200
Consumer-related cost, non-domestic	87,000
Restricted-use, domestic	707,250
Restricted-use, non-domestic	16,000
Restricted-use, Hopkinson	69,500
Normal-use, domestic	1,276,800
Normal-use, non domestic	1,324,300
	$3,638,050

The Hopkinson tariff for high-load-factor consumers would be $19.25 per kilowatt annual plus 0.8c per kilowatt-hour for the smaller consumers whose average normal-use units should cost 1.899c per kWh and for very large consumers whose average normal-use unit rate should be 1.425c per unit the tariff would be $10.95 per annual kilowatt of maximum demand plus 0.8c per kWh. These tariffs can be altered to various combinations of kilowatt and kilowatt-hour charges.

political and sociological reasons. Thus the final tariff can become somewhat meaningless as far as true economics are concerned.

Tariff preparations showing how the theoretical approach is varied by political reasons is shown in the appendix.

The main theme of this paper is that an electricity unit is a unit of work and therefore that all units should have the same basic value for free-use conditions. With this fundamental requirement satisfied, any variations in the value of the unit for different uses should be the subject of a political and social study rather than for engineering economic justification. In brief tariffs throughout New Zealand could be standardised in this fashion.

By framing tariffs along the lines suggested the general pattern could be made more uniform, and most authorities after close examination would find it possible to achieve similarity with their neighbours. Many present tariffs could be improved to the benefit of public relations while still preserving the necessary revenue return.

The rights of supply authorities to determine the revenue proportions between consumer classes are recognised, but it is felt that some so-called "preferences" in loading extra costs on to certain classes of consumers are unwise and detract from the supply authority's standing in the opinion of the public.

AUTHOR'S INTRODUCTORY REMARKS

T. E. KELLY (Hawke's Bay E.P.B.)—My main purpose was to set the stage for a frank discussion on electricity tariffs. The Tariff Committee is charged with investigating them in the quest for more uniformity. The committee seeks your ideas.

Examining the various tariffs throughout the country is both illuminating and disturbing. Some appear almost unreasonable, and one could be very critical of their impact on the consumer's cost of power. I strongly urge you to examine your own tariffs carefully and critically, as this is a case where not only must justice be done, but it must also be seen to be done.

During the meetings of the Tariff Committee over the past two years, and the negotiations with the N.Z. Electricity Department over the bulk supply tariff, I became very conscious of the shortcomings of trying to make a tariff to fit a theoretical method of costing. The N.Z. Electricity Department attempted to justify a costing which, at 50% load factor, included more than a 65% energy cost. The engineer representative on your

committee could not justify any greater share than 27%, the final negotiation figure was about 33%. The U.K. Central Electricity Board appears to include about a 60% energy charge in its bulk supply cost. For Ontario Hydro, the figure seems to be about 40%, while in Oslo, with an annual load factor of 57%, the energy content is 20%, and in New South Wales it is about 39%. This illustrates the variety of thinking.

As our negotiations progressed, I became convinced that the form of the selling tariff should be the one most suitable to the buyer, not the seller. I do not mean that the seller should not recover his costs, but the form of the tariff should be such that the purchaser feels that he is getting a fair deal and can give the best service to his consumers. So it should be with retail tariffs, and this is the principal behind my paper. I am not alone in considering that the maximum demand method of arriving at tariffs is of doubtful benefit. A recent paper on tariffs in Britain says, in brief, that tariffs based on group-load-factor costing, though they cover the total cost, actually are most unfair in their effect on classes within the groups. Similarly, a British friend tells me that some quite heavy costs have to be allocated in an arbitrary manner.

Just as there are many differing opinions on the correct proportion of energy cost in generation, so we have a similar divergence of opinion in distribution. Taking two examples from above, at 50% load factor in Norway, energy cost is about 37% of distribution costs, while New South Wales appear to disregard the question of energy cost. In the United Kingdom consumer tariffs appear to be established on group load factors and diversity, and the following tariff has been quoted for domestic consumers:

Quarterly:

First 68 kWh at 6d, plus balance at 1.75d per kWh, the latter having been calculated from a demand-related element of 1.17d and a unit-related element of .58d.

On the first page of my paper I refer to overloading present revenue with current capital expenditure, and thus eroding any favourable margin in the cost of electricity over other fuels. Unfortunately, at present we have an economic crisis and most of us have attempted to ease our difficulties in obtaining loan moneys by raising the tariff to our consumers.

In the case of my own Board, this has meant that, including loan repayments as being money spent on capital works, 100% of our annual capital requirements are met out of revenue. This has increased the cost of electricity by some 5½% and, coupled with the increased requirements from the State, means that the cost of electricity to consumers will be increased this year by roughly 17%, to provide for an immediate capital contribution out of revenue instead of financing from borrowed money. The balance, making up a total of 24%, was occasioned by the new type of tariff and the necessity to stabilise the cash position of the Board.

I feel quite strongly that, although such moves may be required temporarily because of the economic situation, they should not continue any longer than necessary. It can be proved that capital construction out of revenue does not necessarily bring the cheapest tariff to a consumer. I would like to see a close investigation into this problem so that good advice can be given to supply authorities.

Many will disagree with my suggestion that all units sold should, apart from the consumer-related costs, bear an equal share of the actual supply authority costs. I acknowledge that it might be possible to divide capital costs more accurately between restricted-use units and normal-use units, but of what importance is it? This could result in selling restricted-use units cheaper, and normal-use units dearer, but then a supply authority would be tempted to increase the price of restricted-use units so that the others can be sold cheaper. In the end one probably comes to the same result.

Having prepared a tariff as correctly as possible, one must examine it from a political and sociological aspect. There can be many reasons why tariffs should be varied, taking no account of the mathematical or economic approach, and if these are sound it is just that the tariff should be varied to the ultimate advantage of all electrical consumers. Development of electric usage often requires variations which cannot be balanced against the true cost of electric power, and it is in this field that political judgement can often be more accurate than economic reasoning. It is important, however, that variations should not be large, causing resentment among other power users.

Officials of the North of Scotland Hydro-electric Board tell the story of a dear old lady in a Highland village whose daily consumption was so low that the local officers thought her meter must be defective. It was not, and it was not until she was interviewed that the mystery was cleared up. It turned out she switched on the lights only long enough each evening to find her candles!

Discussion

S. R. Anstice (Dunedin C.C.)—Mr Kelly supports a price per kilowatt-hour on the basis that 1 kWh is exactly the same as another. Is not this approach too limited? The future will see more competitive selling in the energy field, and if we are to market electricity intelligently we need to retain freedom in selective pricing of the kilowatt-hours that we sell. Cheap units, which Mr Kelly classes as restricted-use units when demands for electricity are low, are really a particular aspect of selective pricing and there are other aspects which are not less important although not quite so obvious.

P. B. Priest (New Plymouth C.C.)—In the Appendix there is reference to the Hopkinson-type tariff for industrial consumers and it mentions high-use consumers, smaller ones, and very large ones, and it says that tariffs can be altered to various kilowatt stages. Is Mr Kelly favouring having a tailor-made tariff for different consumers?

R. R. Brown (Hutt Valley E.P.G.B.)—Mr Kelly draws attention to the domestic tariffs developed to be cheaper than non-domestic ones. That will affect electric supply operations in those areas where natural gas will be supplied.

The proposed tariffs for natural gas will be the reverse of the electrical tariffs in that the tariff for commercial and industrial use will be about half that for domestic, and when you compare the electrical commercial or industrial tariff with the proposed or likely natural gas tariff for the same purpose, you will find quite a disturbing discrepancy. In the case of my Board the average gas tariff could be as low as 1.4c per therm—whereas our average electricity tariff for the year just ended was 4.6c per therm. In tariff framing in comparison with or in competition with natural gas, one will have to take such things into account, and may well have to have a good look at the domestic tariff in relation to the commercial and industrial

tariff. And you will still be disturbed because even the domestic price of natural gas will be cheaper than electricity by at least 10%.

R. R. DEANE (Wairarapa E.P.B.)—I am glad that Mr Kelly has suggested that the basis of retail tariffs should be influenced by political and social conditions as some consideration should be given to the consumer's ability to pay.

In the paper, reference is made throughout to load factor. It is perhaps a little unfortunate that it has not been qualified, because in some instances it refers to the consumer's load factor. A consumer's installation load factor need not be coincident with the demand on the supply authority's system, or it could be coincident with it. Has that factor been taken into consideration?

G. S. RUSSELL (Central Waikato)—Would Mr Kelly state what he thinks should be the right proportion that the present generation of consumers should make towards the capital contribution?

E. B. MACKENZIE (N.Z. Electricity Department)—In considering the income received by the New Zealand supply authorities it is important to remember that 57 to 59% of all their energy sales come from domestic consumers. That is higher than most other countries. New Zealand is also unique in that it sells domestic electricity cheaper than for most other uses.

With industries, one knows not only what they use, but also what they use it for. This is not so in the domestic field and there is need for some research. This was briefly commented on in the report of the Power Requirements Committee. The N.Z. Electricity Department has sought advice from a firm of consultants which has done this work in related fields—a consumer study. We have obtained a price from them for carrying out a pilot scheme in three or four electric supply authority areas and we propose to carry it out in the Southland area in some detail. It means taking samples and in the first instance we have suggested domestic consumers.

A proposal recently put to the Electricity Supply Authorities Association is that the department should carry all the management consultant costs and that, if supply authorities join in the pilot scheme, the cost of work that has to be done in their particular areas should lie where it falls—with the Department carrying all the cost of the consultants' advice. We hope to start within the next 12 months.

A. H. HEIR (Electricity Supply Authorities Association)—Mr Kelly in his opening said: "It could be expected from the close liaison between areas". That is the first error in this paper because from my experience there is a minimum of this close liaison between authorities. I can quote an example of two adjacent areas, where one was being forced into altering its tariff because of the other's, until quite by chance it was discovered that the second area was about to drop that particular tariff because it lost revenue.

The work of the Tariff Research Committee will not be done, as Mr Kelly carefully explained, by members of the committee, but every authority in the country will be invited to take some part in some research into tariffs.

Mr Kelly describes the present set-up very well when he comments: "This whole system is founded on very insecure reasonings."

AUTHOR'S REPLY

T. E. KELLY (Hawke's Bay E.P.B.)—There is no doubt that an electricity unit is a unit of work and that it has still the same value whatever it does, but Mr Anstice is entering the field of selling, and if you want to sell a unit of electricity for a certain purpose, obviously you can sell it cheaper—but that is political. It has nothing to do with fundamental pricing. You cannot say that just because a kilowatt-hour happens to be used at 5 p.m. it is dearer than one which is used at 2 p.m. The consumer could not understand that and he is the man who pays.

In reply to Mr Priest the Hopkinson-type tariff is introduced to benefit those who are round-the-clock users. In its wisdom a supply authority might introduce a higher demand charge with a smaller unit cost which should have the benefit of moving the loading away from the demand time. One of the unfortunate things that has happened recently with changing from a quarterly-demand tariff of purchase to an annual demand plus a kilowatt-hour charge is the difficulty of trying to maintain parity between one authority and the next. Those difficulties were often magnified five or six times because the smaller user was the one generally with the high load factor. With the larger use, for some reason or another, the load factor tends to fall, and the benefits are difficult to proportion, therefore we need not change. You do therefore have to tailor your maximum-demand and kilowatt-hour charges to suit what you want to do, not to suit the individual—to suit the particular circumstances.

In reply to Mr Dean, the load factor is the load factor of the consumer. If a consumer is a 40-hour-week consumer it could be that his diversity factor would be zero and he would not be on the authority's peak at all. I was just illustrating how poor a load factor these 40-hour-week consumers give. A commercial consumer should work considerably more than 40 hours per week.

I presume Mr Russell does not want me to get into a discussion about the recent 25% increase. Referring to capital out of revenue, of the authority's own costs, a lot depends on its rate of growth. It was made clear last year by W. G. Johnstone that, unless the rate of growth of an authority is greater than the current interest rate, it is wiser to do work out of revenue. Many of us, however, are growing faster than the current interest rate, and naturally our best method of financing is from borrowed money. But, coming down to the actual capital charges by an authority, the line of demarcation is the building that you do for new consumers or consumers of the future. When you have voltage difficulties or overloading of systems which are created by the consumers of the present, in my opinion that is a fair charge against current revenue directly, but anything else which entails building for the future is best financed from new investment capital.

VOTE OF THANKS

A. S. DON (Auckland E.P.B.)—Today Mr Kelly has produced something of real value to this industry. He has advanced some new techniques, advocated certain theories for costing, and adduced reasonably strong arguments to support all these contentions. Then in his final paragraph he throws them all overboard and suggests that one should rely on political and social reasons only! Many of us will not altogether agree with many of his theories, but all of us will make reference to what is said in this paper.

Communications and data-logging equipment

R. C. W. HOWES, C.Eng., M.I.E.E., M.N.Z.I.E. and D. R. GRANT, B.E. (Hons.), M.N.Z.I.E.

(Design engineer, Dunedin C.C. Electricity Department) (Senior design engineer, electronics group, A. M. Tait Ltd.)

This paper, which describes equipment being supplied to the Dunedin C.C. Electricity Department, shows the great advance that has been made in the local design and manufacture of such equipment.

1 INTRODUCTION

WITH four existing generating stations and a further station due for commissioning in 1968, the Dunedin City Corporation Electricity Department will have a total generated output of 55 MW available to the area of supply. All the generating stations are sited on the Waipori River approximately 30 miles from the load centre in Dunedin.

For a number of years the Dunedin C.C. Electricity Department has been aware that, with the need for accurate control and reliable communication between the system control in the centre of Dunedin and the Waipori generating stations, an efficient system of recording generation data at the system control, and for providing a high level of communication between Waipori and Dunedin was necessary. With this in view a full investigation was made to establish: (a) The best method of presentation of data to ensure efficient control of the system load; and (b) the most suitable form of communication media to link Dunedin and Waipori.

Resulting from this investigation, specifications were prepared and tenders called for the supply of data-logging and communication equipment with preference being given to a manufacturer who was able to tender for both, thus ensuring that problems relating to co-ordination between the two equipments were kept to a minimum. The contract was awarded to a New Zealand firm and both the communications equipment and the data logger are expected to be fully operational early in 1968.

The data logger will present full details of the generated output of each station together with the total system load, total Waipori generated load and the imported load from the N.Z. Electricity Department. In addition analogue and digital displays will be provided showing discrepancies between the imported load and a pre-set target load, and also system loadings.

The communication system provides telephone facilities between Waipori, three intermediate substations which are situated between Waipori and Dunedin, and the system control, together with the data link, 33 kV o.c.b. intertripping facilities, substation common alarms and injection-frequency signalling circuits. The main portion of the communication link operates at carrier frequency over open-pair telephone lines and the underground cable section is at voice frequency. In order to provide a high-security system, it was felt necessary to duplicate the data link. Automatic changeover facilties on the terminal equipment are therefore provided and will come into operation in the event of failure of an open-pair telephone line or a fault occurring on the terminal equipment.

The system arrangement, showing the interconnections between Waipori and Dunedin, are given in Fig. 1. The centre of control at Waipori is at No. 2 station, Nos. 1, 3 and 4 stations being unmanned and remotely controlled from No. 2 station, which is the Waipori terminal point for the 33 kV lines and the open-pair communication lines.

2 REQUIREMENTS OF THE DATA LOGGER

The data logger and its associated analogue, graphical and digital displays are situated in the control desk at the system control centre in the heart of Dunedin. It's main function is to print out automatically at half-hour intervals, or more frequently on demand, the output of the generating stations at Waipori, the total system load, the N.Z.E.D. gross import, the N.Z.E.D. gross reactive-power import and the N.Z.E.D. net import power. This latter information is obtained by subtracting the outputs of Stations 2A, 3 and 4 from the N.Z.E.D. gross import power, for, as can be seen from the system diagram in Fig. 1, the output of these three stations feed directly into the N.Z.E.D. grid. Furthermore, a print-out of the state of the 22 channels of the injection-frequency equipment is also provided. At the end of a 24-hour period, the total system load and Waipori total load in kilowatt-hours are automatically printed out.

In addition to the automatic half-hour print-outs, a print-out cycle is initiated by (a) the operation of the injection-frequency equipment, (b) by manual control and (c) automatically by a comparator alarm which operates when the net import from the N.Z. Electricity Department exceeds a pre-set target load.

Associated with the data logger is an analogue display of the generated output of each of the five stations, the total system load, the total Waipori load, the N.Z.E.D. gross import, the N.Z.E.D. gross reactive import and the N.Z.E.D. net import power.

Digital displays in kilowatt-hours show the integrated totals of the N.Z.E.D. net import and the target load. The discrepancy or difference in these two quantities is also displayed and is prefixed by a negative or positive sign.

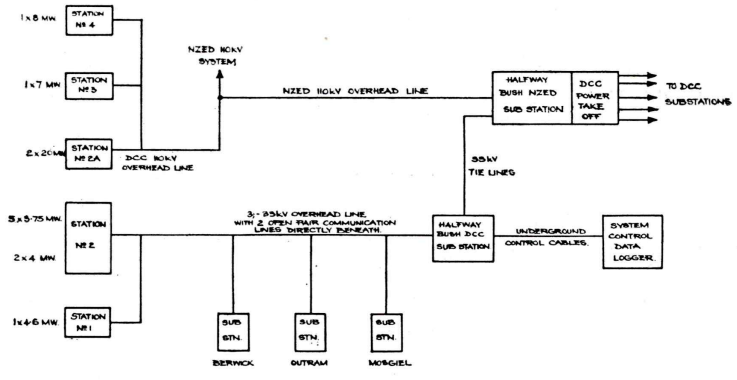


Fig. 1—System arrangement showing interconnections between Waipori and Dunedin

Graphical displays are given on two recorders, a dual-pen recorder showing system load and ambient temperature and a single-pen recorder showing the difference between the net N.Z.E.D. import and the target load.

The system controller is therefore immediately able to observe the generating condition of each station at Waipori, the load taken by the system and, if necessary, control the imported load by means of the injection-frequency equipment, the controls of which are also housed in the control desk.

3 CHOICE OF COMMUNICATION AND DATA LINK

Before a decision could be made on the form of link over which the data and communication would be transmitted from Waipori to the data logger, it was necessary to make an engineering and economic study of the various media available for this purpose.

The following five alternatives were considered:

(a) Open-pair telephone line operating at carrier frequency

This was considered the most suitable form of transmission media, but necessitated the complete renewal of the existing open-pair telephone lines which are installed beneath the 33 kV power lines. Particular care was given to the construction and positioning of the transpositions on the open-pair lines.

(b) Open-pair telephone lines operating at voice frequency

This scheme also entailed the renovation of the existing lines but with a frequency range of 300 to 3,400 c/s, a limitation was placed on the number of telegraph channels that could be utilised.

(c) Duplicate aerial cables ultimately operating at carrier frequency

No engineering advantage was to be gained by this form of transmission media and the cost was much higher than renovation of the open-pair lines.

(d) Power-line carrier on two of the three 33 kV lines

This proposal utilised a phase/phase coupling. The cost of the terminal equipment brought the overall cost above that of the other alternatives. Over a greater distance power-line carrier would have undoubtedly been much more competitive.

(e) Radio link

Consideration was originally given to v.h.f. radio link but no frequencies in that range were available. Subsequently u.h.f. was considered but, in order to provide a "line of sight" signal path required at this operating frequency, it would have been necessary to install a repeater station. The terminal and repeater stations would have been required to be built on difficult hilly terrain and costs of the civil works involved brought this proposal above that of the selected scheme. A further disadvantage to this scheme was that no provision could have been made for telephone communication between the intermediate substations and the system control.

4 REQUIREMENTS OF THE COMMUNICATION SYSTEM

The choice of a duplicate communication link operating at carrier frequency over open-pair telephone lines allows a wide range of intelligence to be transmitted between Waipori, the intermediate substations and the system control and fully caters for the requirements of the Dunedin C.C. Electricity Department.

TABLE I—TELEPHONE AND TELEGRAPH CHANNELS

Channel No. and frequency	*Purpose*	*From*	*To*
No. 4, 64 and 56 kc/s	300 to 3,400 c/s telephone	System control p.a.b.x.	Waipori No. 2 station
No. 5, 72 and 80 kc/s	Waipori gen. stn. No. 1 MW output	Waipori No. 1 station	Data logger
	Waipori gen. stn. No. 2 MW output	Waipori No. 2 station	Data logger
	Waipori gen. stn. No. 2A MW output	Waipori No. 2A station	Data logger
	Waipori gen. stn. No. 3 MW output	Waipori No. 3 station	Data logger
	Waipori gen. stn. No. 4 MW output	Waipori No. 4 station	Data logger
	N.Z.E.D. gross power import	Halfway Bush N.Z.E.D. substation	Data logger and Waipori No. 2 station
	N.Z.E.D. gross reactive-power import	Halfway Bush N.Z.E.D. substation	Data logger
	Standby time control for printometers and data logger	Halfway Bush Dunedin C.C. substation	Data logger and Waipori No. 2 station
	Emergency signal for operation of injection-frequency control	Waipori No. 2 and data logger	Halfway Bush Dunedin C.C. substation
	Distance protection intertripping	Waipori No. 2 station and Halfway Bush Dunedin C.C. substation	Halfway Bush Dunedin C.C. substation and Waipori No. 2 station
	Waipori power stations supervisory control spare telegraph channels	System control	Waipori gen. stations
No. 6, 88 and 96 kc/s	300 to 2,600 c/s telephone	System control p.a.b.x.	Berwick substation
	General substation alarm	Berwick substation	System control
	Injection-frequency control initiating signal	Halfway Bush Dunedin C.C. substation	Berwick substation
	Check-back injection-frequency control signal	Berwick substation	Halfway Bush Dunedin C.C. substation
	Future supervisory control	System control	Berwick substation
No. 7, 104 and 112 kc/s	300 to 2,600 c/s telephone	System control p.a.b.x.	Outram substation
	General substation alarm	Outram substation	System control
	Injection-frequency control initiating signal	Halfway Bush Dunedin C.C. substation	Outram substation
	Check-back injection-frequency control signal	Outram substation	Halfway Bush Dunedin C.C. substation
	Future supervisory control	System control	Outram substation
No. 9, 136 and 144 kc/s	300 to 2,600 c/s telephone	System control p.a.b.x.	Mosgiel substation
	General substation alarm	Mosgiel substation	System control
	Injection-frequency control initiating signal	Halfway Bush Dunedin C.C. substation	Mosgiel substation
	Check-back injection-frequency control signal	Mosgiel substation	Halfway Bush Dunedin C.C. substation
	Future supervisory control	System control	Mosgiel substation

The requirements for each physical circuit were four telephone circuits to operate through the existing p.a.b.x., providing communication between the system control, three intermediate substations and Waipori No. 2 station, together with the following telegraph channels:

(a) Individual outputs of five generating stations transmitted from Waipori to the system control for analogue display.

(b) Combined outputs of stations 1 and 2 transmitted from Waipori to the system control in digital form for data processing. (Stations 1 and 2 supply power at 33 kV directly into the Department's network.)

(c) Combined outputs of stations 2A, 3 and 4 transmitted from Waipori to the system control in digital form for data processing (Stations 2A, 3 and 4 supply power at 110 kV into the N.Z.E.D. grid).

(d) Combined outputs of all stations transmitted from Waipori to the system control in digital form for data processing.

(e) High-speed intertripping on the three 33 kV power lines operating in association with the distance protection between Halfway Bush substation and Waipori No. 2 station.

(f) N.Z.E.D. gross import power derived at the N.Z.E.D. Halfway Bush substation and transmitted both to Waipori No. 2 station and the system control.

(g) Standby time control derived from a master clock at Halfway Bush substation and transmitted to Waipori No. 2 station and the system control.

(h) N.Z.E.D. gross-import reactive power derived at Halfway Bush substation and transmitted to the system control.

(i) Frequency injection, initiating and check-back signalling between Waipori and the intermediate substations and the main injection-frequency control panel situated at the system control.

(j) Alarm signals initiated at the intermediate substations and transmitted to the system control in the event of o.c.b. tripping or transformer alarms.

In addition to the above telegraph circuits, provision for future supervisory control of the three intermediate substations and 33 kV and 110 kV switching at Waipori, together with eight spare telegraph channels for other future requirements, has been allowed for. A schedule of telephone and telegraph requirements is shown in Table I.

To handle this amount of intelligence five independent carrier channels are employed. For the Waipori/system control telegraph channels the full voice frequency band width is utilised as is also the telephone channel between Waipori and Halfway Bush substation. For the other three substations, speech communication is limited to 300 to 2,600 c/s, the remaining part of the voice frequency bandwidth being utilised for six telegraph channels.

5 CHOICE OF SIGNALLING SYSTEM

In order to achieve fast response times for the analogue displays and to obtain the best performance from the data logger, high-speed impulsing is employed. The impulsing is derived from the kilowatt-hour meters, each of which employs a light cell pick-up device specially fitted to the meter. The meter rotor disc is engraved on the under face with a series of black bars of radial width approximately $\frac{1}{4}$ in, the number depending on the speed of rotation of the disc and the impulse value which has been allocated to the meter. A small indicator lamp is used to illuminate the disc surface near the cell. A simple transistor amplifier is used to amplify the output of the cell to operate a two-tone transmitter. Impulse speeds are up to 25 impulses per second and a two-tone frequency-shift signalling system provides one tone at 30 c/s below the channel frequency and the other 30 c/s above the channel frequency. This allows up to 26 independent signalling channels in the frequency range 420 to 3,420 c/s.

6 PROBLEMS ASSOCIATED WITH THE COMMUNICATION SYSTEM

From the outset it was realised that the major problem associated with the use of the open-pair telephone lines as a transmission media was the proximity of the 33 kV lines which, under line transient conditions, would cause high voltages to be induced in the open-pair lines. Furthermore, in the event of a 33 kV line failure, probable contact would be made with the open-pair lines immediately beneath, raising the voltage of the lines to approximately 19 kV. The effect of these two conditions would cause (a) distortion and interference to the data being transmitted, and, (b) unless adequate precautions were taken, severe damage to the transistorised terminal equipment.

In overcoming the problem of distortion, and interference to the transmitted data, consideration had to be given to that part of the intelligence which could ill afford to have any error occurring between the transmitting and receiving end. No problem arises in the case of the analogue displays of the power generated at each of the stations, minor short-term disturbances are ironed out by the relatively long time-constant of the display metering, which is in the order of five seconds, and therefore disturbances lasting less than a second will have little effect on the displays. In the case of the digital information transmitted for data processing, however, a transient fault could seriously affect the results recorded by the data logger. The three outputs in digital form affected are the combined power outputs for Nos. 1 and 2 stations, the combined power outputs for Nos. 2A, 3 and 4 stations and the combined power output of the five stations. By summing these three power outputs at the transmitting end, encoding the information, introducing an error-detecting system and finally decoding at the system control centre, the incident of false information being accepted and recorded has been eliminated. A latter

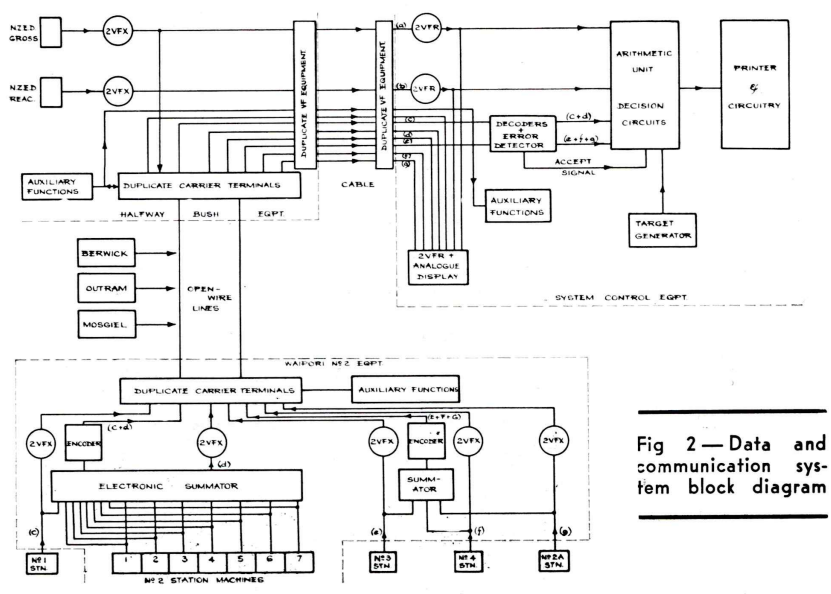


Fig 2 — Data and communication system block diagram

section of this paper covers the detail of the system of error detecting which has been employed. Figure 2 shows the data and communication system block diagram.

To protect the transistorised equipment from the induced voltages on the open pair lines and also from substation and power station earth potential rise, in the event of a fault, it has been necessary to install isolating and neutralising transformers at all cable and line terminations. Originally it was thought only necessary to provide for protection on the open-pair telephone lines, but on further investigation it was found under certain conditions, considerable induced voltages were evident in the pilot cables lying close to power cables, and these too required protection in order to meet the requirements of the Post Office, the N.Z. Electricity Department, and to protect the equipment.

7 V.F. EQUIPMENT DESIGN

7.1 Telegraph equipment

Previous mention has been made of the method of obtaining a number of telegraph channels on a single pair or in a single channel.

The two-frequency signalling equipment (2VF) has been designed for a 60 c/s frequency shift at channel centres of 120 c/s, giving 26 channels from 420 c/s to 3,460 c/s. This is two more than the CCITT standard for a speech channel but the pass-band of the carrier system allows six signalling channels above 2,600 c/s.

A line diagram of the transmitter and receiver is shown in Fig. 3. The transmitter contains a stable *LC* oscillator using *n-p-n* transistors to reduce temperature effects. The frequency can be lowered exactly 60 c/s by the application of a d.c. voltage to the d.c. input terminals. The output amplifier can deliver a maximum level of —2 dbm into 600 ohms and the level can be reduced 20 db to allow for a variation in the number of channels on the carrier system. The transmit filter removes sidebands due to the frequency modulation and allows channels to be operated directly in parallel.

The receiver filter provides channel selectivity and all input signals are raised to a fixed level for application to the discriminator. The discriminator is the dual of the well-known parallel tuned circuits in series. The output circuit is a current switch of low impedance. The output voltage is in step with the d.c. input to the transmitter. The input receive level can be reduced to below —20 dbm without affecting operation.

The combined performance of the channel yields a telegraph distortion of less than 1% at 50 bauds over the full temperature range and for 20db variation in input level.

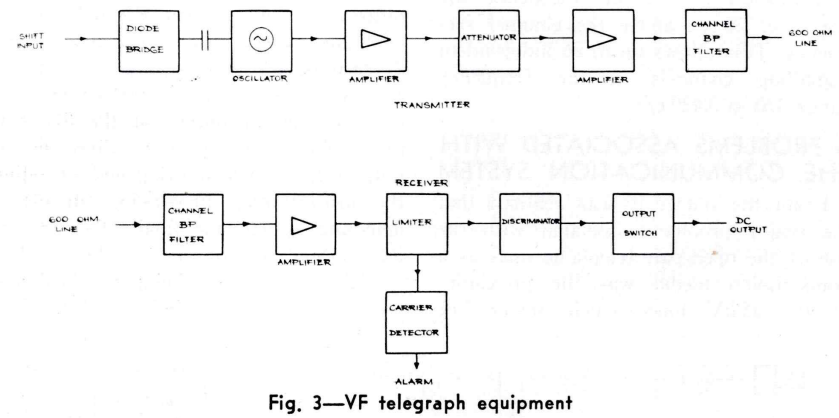


Fig. 3—VF telegraph equipment

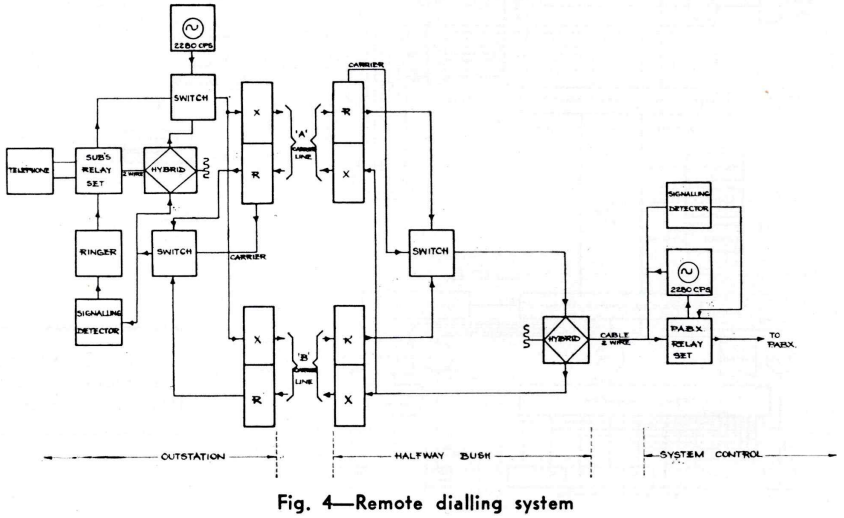


Fig. 4—Remote dialling system

7.2 Remote dialling

The specification calls for remote access to a p.a.b.x. from the three intermediate substations and the Waipori control centre. An in-band signalling system, using speech-compensated detection is used.

A line diagram of the signalling system is shown in Fig. 4. When 17 c/s ringing is received by the p.a.b.x. end relay set, a tone of 2,880 c/s is fed to the 2-wire line at a level of —18 dbr. This tone is detected at the subscriber end by a speech-compensated detector with a guard ratio of 10 db. This means that the level of 2,280 c/s must exceed the total level of the remainder of the speech band (less the 2,280 c/s) by at least 10 db before the subscriber relay set is operated. When the 2,280 c/s tone is received and accepted 17 c/s ringing is transmitted to the telephone.

When the remote subscriber answers, the d.c. loop of the telephone blocks the 17 c/s ringing and operates the subscriber relay set. The 2,280 c/s tone in the inward direction is removed and a detector at the p.a.b.x. end provides a d.c. loop via the p.a.b.x. end relay set which switches the p.a.b.x. to accept the call.

A similar operation of the relay set provides remote dialling. The outward 2,280 c/s tone is unused. Dialling at 12.5 pulse per second is transmitted.

The p.a.b.x. end remote-dialling sets are at the system control centre to remove the necessity of a d.c. path from the carrier terminals at Halfway Bush to the system control.

8 CARRIER-FREQUENCY EQUIPMENT DESIGN

A double-sideband plus carrier amplitude-modulated system was chosen for the carrier equipment. This method has the following advantages over the more common single-sideband amplitude modulated:

(a) The equipment is inherently more simple than single sideband as no sideband filters are required and re-insertion of a carrier is not required before detection.

(b) A continuous check can be made on a large part of the carrier equipment by monitoring the received carrier signal strength.

(c) The accurate carrier frequency must be generated only at the transmitter. This is mainly an advantage where only single channels are dropped off at points along the line.

The carrier system includes compandors for signal-to-noise ratio improvement. These are carefully matched compressor/expander pairs with a compression ratio of 2 and can improve the signal to noise ratio by at least 20 db.

A line diagram of the carrier system is shown in Fig. 5. The speech bandwidth of the transmitter is restricted before modulation to 300 to 3,400 c/s for a full bandwidth channel and 300 to 2,600 c/s for a combined channel. The transmitter is capable of sending +3 dbm to the open-wire line.

The receiver amplifier reduces variation in received line level of ± 6 db to less than ± ½ db. The low-pass filter following the detector cuts off at 3,400 c/s. In the case of a combined channel a second filter follows the take-off point to prevent the telegraph channels appearing in the audio output.

Hybrids for 2-wire to 4-wire conversion form part of the remote-dialling equipment.

Failure of the carrier channel is detected by the absence of the received carrier and this is indicated as an alarm condition. In the case of the Waipori-Halfway Bush channels, failure of one carrier changes the duplicate control to the opposite channel. Both carrier channels transmit and receive at all times and duplicate switching is performed on the receiver outputs.

9 THE ERROR-DETECTING SYSTEM

The error-detecting system consists of a data transmitter and receiver. The transmitted pulse train contains sufficient redundant information to determine with a high probability that the message contains no errors.

Block diagrams of the transmitter and receiver are shown in Figs. 6 and 7.

The input information, which is a series of impulse trains, is separated from the main counters by a temporary memory so that the transmitted data cannot be changed when the link is transmitting data. The encoding gates are scanned by the encode generator to form a pulse train. Each line (1 decimal digit) has a line-parity bit added to form an odd parity word (i.e. always an odd number of pulses per word). The combined pulse train containing data and line-parity bits is fed to the data 2VF channel and to the parity calculator where a 12-bit parity word is formed.

The parity calculator is the heart of the error-detecting system. The calculator takes the data pulse train (considered a variable in x) and divides it by the polynomial $x^{12} + x^{10} + x^8 + x^5 + x^4 + x^3 + 1$. At the end of the pulse train the memory of the calculator contains the remainder from this division and this remainder is transmitted to line. When the parity word is completed a frame signal is initiated.

The transmitter scans continuously, irrespective of the input information. Synchronisation between transmitter and receiver is assured by a second 2VF channel.

9.1 Data receiver

The frame signal is extracted from the synch 2 VF channel and controls the synch line to prevent interference during the frame interval.

The data 2 VF channel output is strobed with the synch signal so that only data received during the correct time interval is accepted.

The accepted data is fed serially to a shift register memory, to a parity calculator identical to that of the transmitter and to a line-parity detector.

At the end of the data and line-parity train a comparison is made of the contents of the receiver-parity calculator

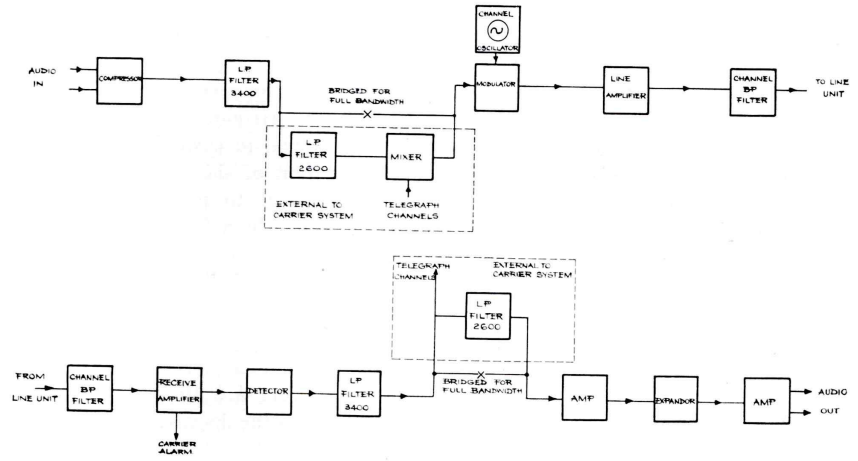


Fig. 5—A line diagram of the carrier system

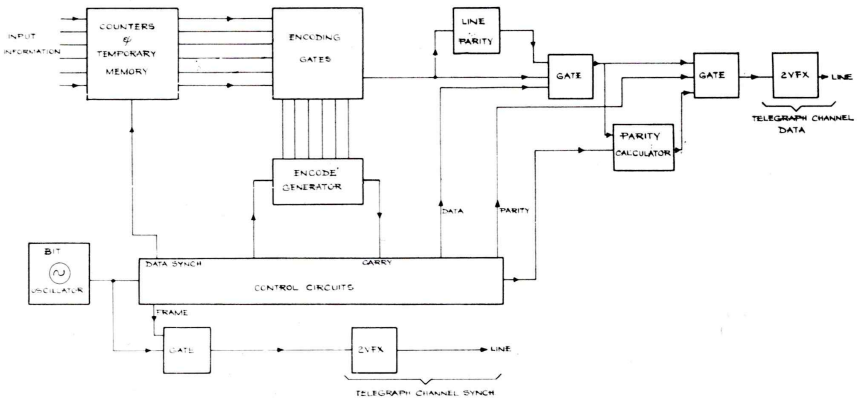


Fig. 6—Block diagram of data link transmitter

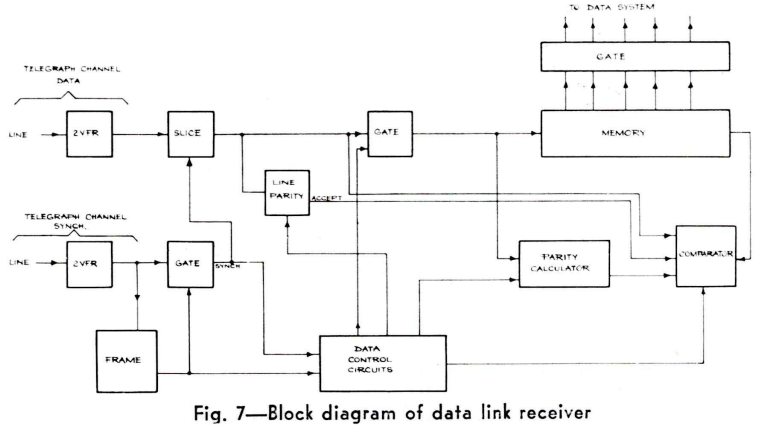


Fig. 7—Block diagram of data link receiver

and the incoming pulses from the transmitter-parity calculator. If these bits and the line-parity bits agree, the message is accepted and the contents of memory transferred to the main data-logger memory.

9.2 Security

The security of the system is based on the choice of the parity calculator polynomial. A 63 12 Bose Chaudhuri code (contains 63 bits per frame of which 12 bits are parity bits) can be formed using the chosen polynomial and this must have no parallel code in noise circuit pattern. Extensive investigations by both Bell and IBM have shown that this code bears no noise pattern relationship. In simpler terms, as long as the interfering noise pattern cannot operate on the data pulse train to form the same remainder in the parity calculator a perfect error detection can be achieved.

If an error is detected, the information contained in the receive memory is ignored and the receiver will wait for the next correct pulse train before a transfer to the data logger can occur.

10 DATA LOGGER

10.1 Analogue display

Moving-coil meter displays are provided for:

(1) N.Z.E.D. gross power.

(2) N.Z.E.D. gross reactive power.

(3) Power output Waipori 1.

(4) Power output Waipori 2.

(5) Power output Waipori 3.

(6) Power output Waipori 4.

(7) Power output Waipori 2A.

(8) Waipori total power.

(9) System total power.

(10) N.Z.E.D. net power.

Graphical displays are provided for:

(1) Discrepancy, i.e. difference between N.Z.E.D. net and pre-set target.

(2) Combined displays of system total power and ambient temperature.

Figure 8 shows how these displays are provided. The output of the pulse-length circuit consists of a pulse of fixed height (set by the amplifier) and constant length (set by crystal and counter). Thus as the frequency out of the 2VFR is proportional to power, the d.c. content of the output of the pulse length circuit is proportional to power. These pulses are integrated by a 2-stage *RC* integrator and displayed on moving-coil meters. The currents are also added and subtracted in Kirchhoff adders for combined totals.

The meter displays have an accuracy of 0.75% and a time constant of six seconds. There are 10 7×5 in moving-coil meters in the display.

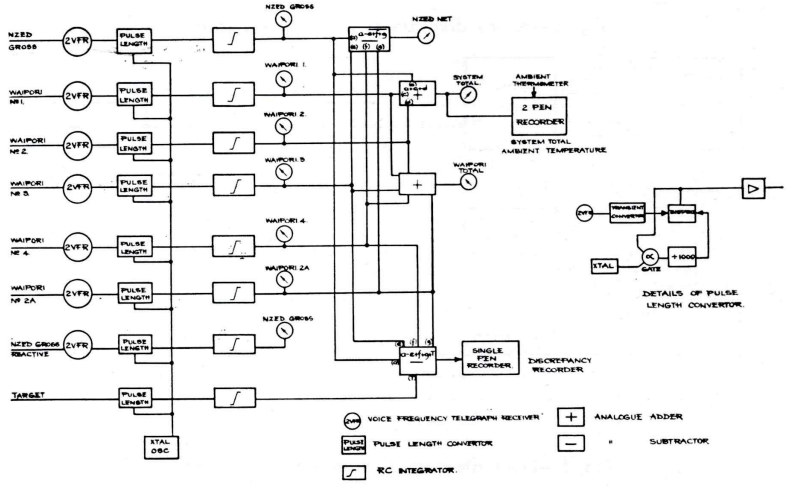


Fig. 8—Analogue display

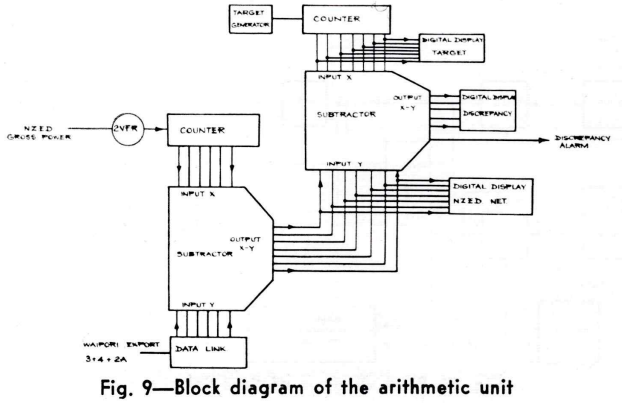


Fig. 9—Block diagram of the arithmetic unit

The graphical display uses two $11\frac{1}{2}$ in potentiometric recorders which have an accuracy of 0.75% and chart speeds are correlated to avoid blotting of the result.

The discrepancy recorder has a span from —10 MW to +5 MW with the centre being the equality of N.Z.E.D. net and target impulse rate. This display acts as a moveable suppressed-zero recorder having a span of 15 MW and a zero print settable from 20 MW to 230 MW. Additionally it will show abrupt changes in load, for example, when injection-frequency control operations are executed, as a straight line across the graph. The recorder has an auxiliary switch which acts as a back-up discrepancy alarm.

It should be noted that both recorders display power and not kilowatt-hour units. Transmission disturbances will be recorded but, as the chart speeds are slow and the pen speeds are set by the chart speeds, the disturbances would need to last some seconds to show on the result.

10.2 Target generator

A target generator is supplied which provides an artificial impulse rate for load monitoring.

The generator consists of a Wein bridge oscillator of high stability. The impulse rate is set by switches calibrated directly in megawatts. Load ranges from 20 MW to 230 MW can be generated. The accuracy of the impulse rate is ±0.2%.

The oscillator operates at 2,048 c/s for 20 MW and the required 25 kWh per impulse is obtained from binary dividers.

10.3 Arithmetic unit and printer

Figures 9 and 10 show block diagrams of the arithmetic unit and printer circuitry.

The Waipori export (sum of Waipori 3, 4 and 2A) is subtracted from the N.Z.E.D. gross to form N.Z.E.D. net. The N.Z.E.D. net is subtracted from the target to form the discrepancy. The subtractors, which are quite complex, perform decimal subtractions in 8421 BCD code and provide true, uncomplemented differences. The overflow signal (termed "borrow") from the discrepancy subtractor is used as a discrepancy alarm signal as this borrow occurs when X is less than Y.

Digital displays using 1 in numerical indicator tubes (nixies) are provided for N.Z.E.D. net, target and discrepancy.

The information presented to the arithmetic unit from N.Z.E.D. gross power, N.Z.E.D. gross reactive power, data link and digital clock are continuously changing. At a half-hour printout

the totals must be recorded very quickly to prevent loss of information. For any of the non half-hour printouts the totals must also be extracted very quickly from the continuously changing counters. The N.Z.E.D. gross and digital clock outputs are slaved to auxiliary memories. These units normally follow the main counters but as soon as a printout is required this connection is broken. For non half-hour readouts the connection is restored at the end of the print cycle. For half-hour printouts the main counters are reset to zero as soon as the connection is broken.

In the case of the data link the information change is prevented by blocking the shift register/memory transfer when a printout is required.

The information to be printed is scanned on to a common print highway using diode gates. One decimal digit is switched at a time. The diode gating is under the control of the serial pulse generator which controls the order of printing. The signals on the highway are amplified, code changed to suit the IBM printer, and then drive the printer via silicon-controlled rectifiers.

Control signals for timing are extracted from the printer. Control of index, carrier return, tab and space are provided. All half-hour automatic readings are double spaced from non-half-hour printings. Tab positions are mechanically set as in a normal typewriter so that certain blocks of information may be emphasised. Automatic suppression of insignificant zeroes is employed. At the end of the half-hour printout for 2,400 hours the system total and Waipori total power is logged. The printer then automatically line spaces to the beginning of the next sheet.

The printer is an IBM 735 (golf ball) input/output writer with a 13½ in writing line. Printing speed is 15.5 digits per second. A printout takes about three seconds.

Figure 11 shows a series of typical printed results.

10.4 Digital clock

A crystal-controlled digital clock is provided. This controls all operations of the machine and provides a source of time for the printed log.

The crystal operates at 100 kc/s and has a long-term rate of about 1.5 parts in 10^7.

The chart drives of the potentiometric recorders are driven from the 50 c/s output of the crystal clock via a s.c.r. inverter so that the chart time scale is unaffected by mains frequency variations or failures.

11 MECHANICAL CONSTRUCTION

The equipment which has been described is entirely transistorised. In the main three transistor groups are used: One germanium *p-n-p*, one germanium *n-p-n* and one high-voltage silicon *n-p-n*. The same transistors are used for the communications and logic circuitry.

The logic design is based on worst-case philosophy in which all variations in components and environment are taken at worst simultaneously. This design method produces equipment of very high reliability. It is also interesting to note that this design method allows all component values to be determined by calculation and no experimental confirmation of choice is required.

Glass-fibre printed-circuit cards are used for all circuitry. Logic cards plug-in to a tray accommodating 20 cards and each tray is equipped with its own power supply isolator. The sockets for these cards contain 39 pins and the interwiring is wire-wrapped.

The printed-circuit cards for the communications equipment are mounted in a separate metal box before plugging into a tray.

Power supply is from nickel-cadmium batteries which are floating on two-rate chargers. This ensures continuity of communications in the event of mains failure.

CONCLUSIONS

The cost for the supply and installation of the data logger and its associated communication equipment is in the order of $60,000 plus the cost of the renovation of the open-pair telephone lines which amounted to $26,000.

The question may be raised whether the expenditure of this sum of money on equipment of this nature was warranted. Several reasons can be given, the most important of these being:

(a) The existing electro-mechanical control equipment was proving difficult to maintain and would be inadequate to cope with the additional generating capacity of the new No. 2A station and also the increase in system load; (b) The response times of indication of Waipori generation and system load was below requirements and a much faster response was necessary for accurate control and efficient economic operation. This could be satisfactorily achieved only by the use of high-speed impulsing utilising electronic equipment; (c) The existing open-pair telephone lines were in need of replacement, the communications between Waipori and Dunedin being sub-standard and subject to interference and distortion. Limitations also existed in the amount of information that could be transmitted between Waipori and

(*Continued on next page*)

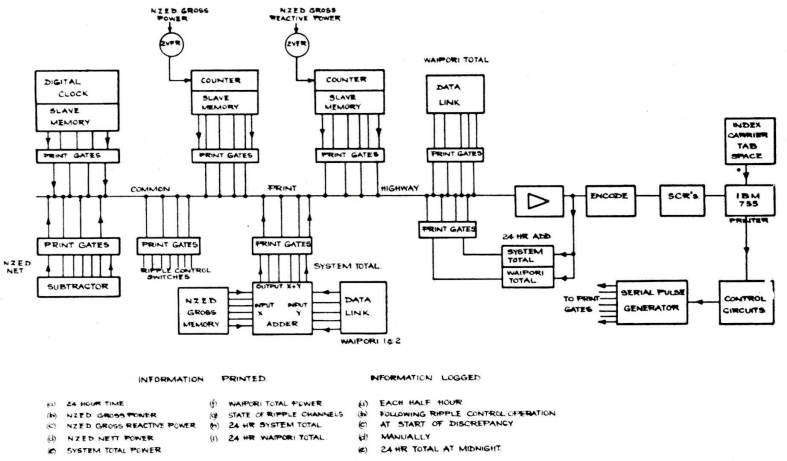


Fig. 10—Block diagram of the printer circuitry

TIME DATE: 1/6/67	SYSTEM LOAD MW	WAIPORI TOTAL GENERATION MW	NETT N.Z.E.D. IMPORT MW	GROSS N.Z.E.D. IMPORT MW	GROSS N.Z.E.D. REACTIVE IMPORT	FREQUENCY INJECTION CHANNEL CONDITION	24 HOUR INTEGRATED SYSTEM LOAD KWH ÷ 100	24 HOUR INTEGRATED WAIPORI GENERATION KWH ÷ 100
00 30	42 40	00 00	42 40	42 40	08 10	XXXXX6XX90XXX45XXXXX1X		
01 00	38 60	00 00	38 60	38 60	07 71	XXXXX6XX90XXX45XXXXX1X		
01 30	36 20	00 00	36 20	36 20	07 24	XXXXX6XX90XXX45XXXXX1X		
16 30	41 47	32 60	58 87	66 90	13 30	XXXXX6XX90XXX45XXXXX1X		
17 00	106 27	46 85	59 42	73 40	14 62	XXXXX6XX90XXX45XXXXX1X		
17 30	107 38	47 45	59 93	64 00	12 80	XXXXX6XX90XXX45XXXXX1X		
18 00	107 77	47 65	60 12 H	74 20	14 84	XXXXX6XX90XXX45XXXXX1X		
18 30	107 40	47 55	59 85	73 90	14 78	XXXXX6XX90XXX45XXXXX1X		
23 00	72 51	12 90	59 61	61 90	12 58	XXXXX6XX90XXX45XXXXX1X		
23 30	61 30	03 00	58 30	61 30	12 26	XXXXX6XX90XXX45XXXXX1X		
24 00	50 50	00 00	50 50	50 50	10 11	XXX4XXXX9XXXXX6XXXX1X	144 00	64 00

Fig. 11—A series of typical printed results

Dunedin. At carrier frequency all present and future requirements can be met.

As can be seen from the foregoing description of the equipment being supplied, a great advance has been made in the design and manufacture of New Zealand-made electronic telemetering and data-processing equipment. For the first time carrier frequency communication equipment is being designed and manufactured in New Zealand and it is hoped that this will be the forerunner of an advance in the electronic industry that will provide for supervisory control, data processing and communication systems for supply authorities and industry throughout New Zealand.

With electronics equipment becoming more and more an essential tool for electric supply engineers, especially in the fields of communications telemetering and supervisory control, it is necessary for the electrical engineer to become more conversant with basic electronics as applied to these fields. It is hoped that in future years a greater emphasis will be placed on electronic engineering as being an essential part of the basic training for the electrical supply engineer, for without this knowledge, the advantages to be gained by the use of electronic control and telemetering equipment in the electric supply industry will be lessened.

ACKNOWLEDGEMENTS

The authors would like to thank S. R. Anstice, general manager of the Dunedin C.C. Electricity Department, for permission to publish this paper and also acknowledge the help that the staff of A. M. Tait Ltd. and the Department gave in its preparation.

Discussion

J. E. COGHLAN (Waimea E.P.B.)—There is no mention in the paper that the open-pair lines are duplicated and this appears to be the weakest link in the whole set-up.

In dealing with error detection mention is made of bit parity words, parity calculators and Bose Chaudhuri codes. Would the authors amplify this?

They also refer to a long-term rate in connection with the digital clock and I have not come across that expression before.

On some of the telephone links they use 0 to 2,600 c/s and in another they use the whole audio range. Why do they use a different band width for each channel?

Much information is transmitted back to Dunedin. Is it all used?

In the lamp and photocell arrangement on the f.l.f. kWh meters it appears there is a weak link there in lamp failure. What is the anticipated lamp life, and the means of maintaining a lamp?

J. D. HAIGH (Bay of Islands E.P.B.)—This paper tends to frighten people with its technical terms, and there are no references and no bibliography.

Why was the job not done by providing 25 miles of aerial cable and erecting it underneath the h.v. power line, thereby dispensing with some items of equipment which are apparently necessary to make this scheme work. The required length of cable could be provided for $36,000, based on the erection of between 27 and 30 miles of 25/20 lb cable, its erection and jointing time, the insertion of 20 span breakers and jointing and erecting materials. I have worked out the loss on this length of cable and have come to the conclusion that each of the intermediate substations could dial into the p.a.b.x. as also could the Waipori power station, by using standard dialling techniques.

How much of the cost of the equipment ($60,000) is involved in that part of the terminal equipment that is really installed to cope with the interference, or the effects that arise from the using of these open-pair circuits that are erected under the h.v. power lines?

There is apparently a very high degree of accuracy provided by the digital clock. Is this high degree of accuracy necessary? Most N.Z.E.D. substations work on a simple clock.

The designer appears to have worked on the number of pulses received and not on the pulsing rate. I understand that the pulse rate method is the most reliable in that, if you lose pulses on the way, the pulse rate itself is not going to be greatly affected.

Many signalling systems of this type, to speed up the impulsing rate, use the technique of varying their gear ratio and do not use the lamp signalling as lamp failure can be difficult. Does the authors' technique obviate the problem?

There appears to be a high degree of accuracy involved in the figures and information received by the controller operator. Is he getting a picture of the Dunedin City Council's check metering, or getting the N.Z.E.D. instrument readings repeated?

J. A. WARNER (South Canterbury E.P.B.)—From the introductory remarks in the paper, that in 1968 the total output of the Waipori stations will be 55 MW, I assume that Stations 1 and 2 will not be generating from this date and that Stations 2A, 3 and 4 will total 55 MW and feed directly into the N.Z. Electricity Department 110 kV system. All the Dunedin C.C. power requirement will then be supplied from the N.Z.E.D. substation at Halfway Bush. If this assumption is correct it seems that much of the equipment being supplied will never be used.

The method adopted by Dunedin C.C. of transmitting 55 MW over quite a long distance is very interesting. Despite its comprehensive nature the analogue and digital information is still only an indication, and if the input of power from the N.Z.E.D. is indicated as greater than the pre-set target, Waipori has to be contacted from Dunedin City, and increased generation requested. How long would it take to achieve this extra output? Would not a logical step be automatic control of the Waipori stations to meet the pre-set load?

I take it that additional control channels would be required for controlling 12 generators if the control centre was located at Waipori instead of Dunedin, this difficulty would not arise as Stations 1, 3 and 4 are already remotely controlled from No. 2 station. Further, locating of the control centre at Waipori would reduce the information required to be transmitted from the total input recorded from the N.Z. Electricity Department at Halfway Bush substation. It would seem that all the other additional information is already available at Waipori. Would not this reduce considerably the cost of the carrier equipment and the error-detecting system required?

In the error-detecting system is there any special indication if a meter pulse fails?

With our system using conventional valves and with preventive maintenance one can check and replace them before failure. Is this possible with transistors and diodes, or do they simply fail?

AUTHORS' REPLIES

Mr Coghlan said it was suggested that there was only one pair of open-pair telephone lines. There are in fact two pairs of telephone lines which are installed underneath different power lines. In the event of a power line coming down the communication system would therefore not be affected.

The error-detecting system is an extremely complicated piece of equipment in operation. In basic principle it is reasonably simple. At Waipori, which is the transmitting end of the system, the summating of the impulses and the sub-totalling is carried out, not at the receiving end. The sub-total is transmitted, as a sub-total, to the system-control end and sufficient extra information is transmitted so that at the receiving end any interference can be detected. Basically, what happens is that the sub-total which is to be transmitted is divided by an algebraic arithmetic unit and the remainder of this is transmitted as well as the information. At the receiving end the same sum is done by a similar piece of equipment, and the two remainders of the division process are compared. If they are not the same, an error has been introduced.

On the comments concerning the long-term rate of the clock this is accuracy on a basic time standard, not in the actual indication of time as shown by the clock. The analogues of the ordinary synchronous clock running off the mains to a frequency of 50 c/s is the basic time standard but the accuracy of the clock is how accurate you set the hands. The quoted rate of one second in about 23 days means an error in the basic frequency. Crystal clocks suffer from one very slight disadvantage, i.e., the change in frequency with time is always predominantly in one direction and this means that as the crystals age the correction has to be made to the basic frequency of the unit, but because of the accuracy of a few parts in 107 that is involved in it one must either have something like the National Standard to compare it with or wait 23 days to see any error.

We generally transmit the audio band widths from 300 to 3,400 c/s. This gives a band width of 3,100 c/s. In the case of the substation the audio-speech band width is limited to 300 to 2,600 c/s which allows us to provide six signalling channels on the remaining part of the spectrum, this is between 2,700 and 3,400 c/s. There are only two band widths in the system.

On the question on what the information transmitted to Dunedin will be used for, I would first point out that the existing system is completely inadequate for the required standard of control, the communication is poor and the amount of information that is transmitted over the open-pair telephone lines is very limited. With the renovation of the open-pair telephone lines it is intended to make full use of them at carrier frequency and a great deal more will be transmitted to system control in Dunedin. This information will be in printed form and will give the history of what has taken place each day, it will allow studies of load trends and tariff investigations, it will enable us to see what effect injection-frequency control has on the load, for a printout is available immediately after control operation.

On the question of lamp life the manufacturer quotes the average life under our operating conditions as 60,000 hours. Dunedin C.C. policy is to change the lamps before 60,000 hours. However, a further lamp has come on to the market with a life expectancy of 150,000 hours, which is an extremely long time.

The suggestion that the use of an aerial cable would seem more economical was looked at in assessing which would be the best way to get the information from Waipori to Dunedin. Mr Haigh might have overlooked the fact that we require the circuit to be duplicated. We could not rely on one aerial cable strung over 30 miles beneath the 33 kV power lines. If anything happened to the single communication link the Dunedin C.C. would be immediately without information and control. Furthermore, with 20 pairs we would have to protect each individual pair with an isolation transformer or neutralising transformer. With open-pair only one set of protection equipment at either end is all that is required.

The cost of the open-pair telephone lines amounted to $26,000. This compared with possibly $72,000 given by Mr Haigh for two aerial cables and the difference is quite appreciable. The system proposed by Mr Haigh was looked into very closely and it was felt that no advantage would be gained by installing an aerial cable. The cost of terminal protective equipment was not included in the $60,000 given in the paper, the cost of the equipment being $10,000.

The question on the degree of accuracy of the clock can be answered by the reason that the crystal, which is the heart of the clock, is not very expensive and crystals start with this sort of accuracy. The basic cost of the crystal itself is about $60. To buy a unit of about 1/10th of the accuracy would still cost about $60 and that is the lowest accuracy a crystal clock could be made for. In answer to Mr Haigh's comment on the method of transmission it should be noted that there are two distinct forms of transmission. On the one hand for analogue displays a pulse rate is used but for the quantities of power as distinct from the number of units, a number of pulses is transmitted.

On the question of gear ratios in preference to the photocell, in order to handle the high impulse rates it would be necessary for a ratio of gearing in the order of 1 to 66 to be introduced. I do not think there is sufficient power in f.l.f. meters to drive a gear ratio of this magnitude.

At Halfway Bush substation, the meters are our meters and are independent of the N.Z.E.D. meters. It is the impulsing from these check meters that is processed at system control.

Mr Warner's assumptions were wrong in that when 2A is commissioned Nos. 1 and 2 will still be operating. This puts a completely different picture on his question. Nos. 1 and 2 stations will generate in the initial stages and it is hoped that approximately 32 to 33 MW from its 3, 4 and 2A and if possible 24 MW from Nos. 1 and 2 will be obtained. With stations 1 and 2 transmitting at 33 kV from Waipori direct into our network, a complication arises, and it is because of this that it is necessary to have the system control at the heart of the city. The Waipori station is fully manned and with a communications system that we will have operating between Dunedin and Waipori we will be able to get in touch with Waipori immediately so that any alteration in generation can be accomplished almost straight away. Indication also exists at Waipori No. 2 station to enable the operators at Waipori to tell instantly the condition of the system load. They can take steps to rectify this immediately without any direction from the city.

Ageing of components, including the transistors, has been allowed for in the design. Basically the answer to the question is summed up by a statement attributed to the Bell Telephone Laboratories that transistors do not die—they just get old. Valves, unfortunately, have the habit of dying, and that is the basic difference. The other consideration is whether Mr Warner would like 4,000 valves in his system, and the 25 kW it takes when he turns the filaments on!

Heating of underground cables

W. G. JOHNSTONE, B.E., C.Eng., M.I.E.E., M.N.Z.I.E.
(Chief engineer, Christchurch M.E.D.)

An investigation associated with the laying of oil-filled 66 kV underground cables in Christchurch has yielded some surprising results. Lack of knowledge of soil conditions, and an inadequate appreciation of all the factors involved where cables are laid close together, have resulted in temperature rises on 11 kV cables very different from those anticipated from rough calculations carried out earlier. The procedure and data required to investigate such conditions are set out in a form which should simplify calculations.

Methods of preventing excessive temperature rises are discussed, and formulae are developed for water-cooling of cables.

1. PRESENT POSITION

THE policy in Christchurch has been to install 11 kV underground cables in built-up areas in preference to overhead lines wherever practicable, and nearly 400 miles of such cable are in service. The cables have generally been rated in accordance with E.R.A. Report F/T 183[1] on the assumption that the soil thermal resistivity is not greater than 120 deg C cm/watt, allowance being made for grouping factors and cyclic loading factors, as set out in the above report. As Christchurch is on flat ground and the water-table is fairly high in winter when the maximum loads occur, it was thought that there was little risk involved in the above assumption.

2. PROPOSED 66 kV CABLES

One of the main points of supply for Christchurch will in future be at Bromley substation, where present plans are for an ultimate firm capacity of 1 million kVA. Outgoing 66 kV underground cables will transmit this power to main district substations, and there are likely to be approximately 30 to 40 of these cables radiating from Bromley along three main routes. The first two of these cables are being installed during 1967, and it was decided to investigate conditions along the route, bearing in mind particularly the following factors:

(i) Bromley substation is in the middle of a sand area.

(ii) There would be a fairly low "grouping factor" owing to the presence ultimately of up to 12 cables along one route.

(iii) The temperature rise permitted on oil-filled or gas-pressure cables is 70°C compared with 50°C on 11 kV belted paper-insulated cables, so that sheath temperatures would be much higher.

(iv) Current loadings would normally be well below the rated full-load value, but under emergency conditions one cable would carry the full-load current or a little more.

2.1 Preliminary measurements of thermal resistivity

Thermal resistivity measurements on site made by means of a probe-type tester were found to vary widely over a range of from 50 to 430 deg C cm/watt (or thermal ohm-cms). Some existing 11 kV cables were in service in this area and it was found that, although the cables were operating well below full load, there was a ring of completely dry sand of up to 6 in radius round them. The thermal resistivity of this dry ring was over 400, and the cable surface temperature was much higher than anticipated.

2.2 Sand analysis

Sieve analyses were obtained from two samples of the Bromley sand, one taken from a place where it was damp and one from a place where it was dry. The analyses were identical, and showed a remarkably uniform particle size. The analysis is shown at A in Fig. 1, which also shows curves for other silty materials found a few miles from Bromley. Superimposed on this figure are curves for the Icklingham sand in the United Kingdom and a specially graded "thermal sand", both of which are given in E.R.A. Report F/T 204[5]. The "thermal sand" has well graded particle sizes, leading to a minimum of voids and consequently a low thermal resistance—not more than about 120 deg C cm/watt even when dry—whereas the Icklingham sand was considered very bad because of the uniform particle size. (It will be seen that the local sand is even worse.)

Bromley is situated approximately two miles from the sea coast, and the sand area extends right to the sea. It appears that the analysis is typical of that obtained from sands on or adjacent to this part of the coast, and that somewhat similar analyses are obtained for sands

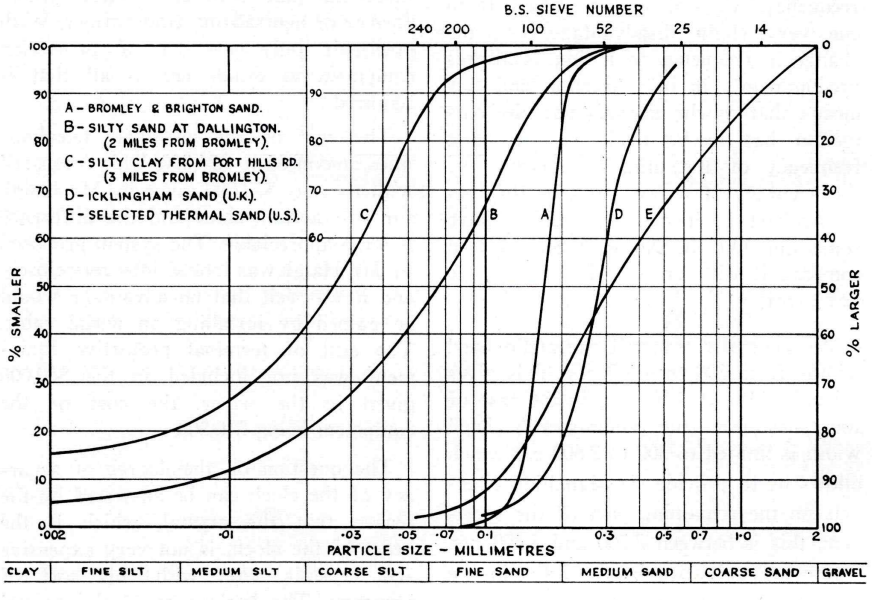

B.S. SIEVE NUMBER
240 200 100 52 25 14
A - BROMLEY & BRIGHTON SAND.
B - SILTY SAND AT DALLINGTON. (2 MILES FROM BROMLEY).
C - SILTY CLAY FROM PORT HILLS RD. (3 MILES FROM BROMLEY).
D - ICKLINGHAM SAND (U.K.).
E - SELECTED THERMAL SAND (U.S.).
% SMALLER
% LARGER
PARTICLE SIZE - MILLIMETRES
·002 ·01 ·03 ·05 ·07 0·1 0·3 0·5 0·7 1·0 2
CLAY
FINE SILT
MEDIUM SILT
COARSE SILT
FINE SAND
MEDIUM SAND
COARSE SAND
GRAVEL

Fig. 1—Particle size curves (sieve analysis)

in other parts of the New Zealand coast, e.g. Paraparaumu. The particles tend to be of larger but still uniform size, at Eastbourne and Wanganui.

2.3 Examples of overheating of 11 kV cables

The necessity of studying the behaviour of the sand in the Bromley area became very apparent as a result of serious heating on 11 kV cables. The particular installation affected in this area consisted of four 0.25 in² 11 kV paper-insulated, lead-sheathed, and armoured cables laid in a rectangular formation at 2 ft and 2 ft 9 in depth approximately, and at 2 ft horizontal spacing. All four cables carried the same current of about 325 A peak which, it has been since calculated, should have given a fairly normal sheath temperature of about 54°C if the soil resistivity did not exceed 120 deg C cm/watt. Due allowance was made in this calculation for normal soil temperature, loss load factor, cyclic loading factor and grouping factor. In fact, the sheaths of the lower cables reached a temperature of 116°C and melted the polythene on adjacent pilot cables. The sand for some distance round the cables was very hot and completely dry.

Emergency action included some load transfer to reduce the heating, the scooping of sand away to form reduced cover over the cable and so reduce the external thermal resistance and the flooding of the depression so formed with water to drop the temperature. As expected, the water flowed away in funnels which it formed without wetting the whole of the sand, but nevertheless the overall result was a fairly rapid drop in temperature. A day later the sheath temperature had dropped to 71°C and on the following day was only 60°C.

A major factor in this incident was the presence of a line of large pine trees parallel to the cables and about 10 ft away from them. The roots of the trees accelerated the natural tendency of this sand to dry out when heated, thus causing the thermal resistivity of the sand adjacent to the cables to rise to over 400 deg C cm/watt. On the same route clear of the trees, the sheath temperature rise was round about the calculated value of 54°C, with only a 2 in ring of completely dry sand round each cable.

2.4 Conclusions regarding drying out of sand

It would appear that in winter the moist sand could have a thermal resistivity of the order of 90 deg C cm/watt, and that this could average about 120 deg C cm/watt in the summer when the moisture content is less. The variation of resistivity with moisture content is interesting—average results being obtained as follows:

Moisture content	Less than 1%	From 2-3%	From 4-7%	From 10-30%
Resistivity .... (Thermal ohm-cms)	Over 400	110-130	80-100	50-70

It appeared that, in summer, with lower moisture contents, there was a tendency for drying out of the sand to less than 1% moisture to proceed by migration of moisture if the sand temperature was raised above 30°C, and this agrees with the result for Icklingham sand given by the Electrical Research Association in their Report F/T 204 (Section 4.3.1.). In winter, drying appeared to commence at approximately 40°C, but this figure is subject to further checking.

As the sheath temperature of the 66 kV cables it was proposed to install in the Bromley sand would in certain circumstances be well over these figures, consideration was given to the following means of providing a satisfactory installation where up to 12 cables are installed along one route:

(a) Use of larger-sized cables to reduce the heat generated.

(b) Use of specially selected thermal backfill above and below the cable which retains a value of resistivity not exceeding $g = 120$ even when quite dry.

(c) Use of water cooling by means of polythene pipes of 2 in diameter supplied with artesian water.

Other methods, such as the use of increased cable spacing, the containment of moisture by artificial barriers round the cable and soil irrigation were not considered practicable.

After a careful study, involving detailed calculations supported by an electrolytic tank model, it was decided that either method (b) or (c) would give satisfactory results, but that the former method was preferable as there was less risk of failure of cooling. The use of larger-sized cables would be more expensive than the other methods, and would moreover increase the imported content of the materials. The cable manufacturer also appeared to favour the use of selected back-fill. It was therefore decided to adopt this method.

In the course of the study, much use was made of E.R.A. reports, and papers published by various authorities. The E.R.A. coverage of the whole subject of cable ratings is most extensive and was of great assistance.

Nevertheless, much time was spent in establishing the correct method of calculation, and in the course of this, it was found that some of the methods used in the past to establish ratings of 11 kV cables where normal daily cyclic loadings were involved gave substantial errors. It was thought that a summary of the methods used would be helpful to those who require to obtain a correct result in a minimum of time, and this information is now set out.

3. CALCULATION OF CABLE RATINGS FOR DIRECT BURIAL UNDER VARIOUS CONDITIONS

3.1 List of symbols

W = total watts loss per centimetre length of cable at current I (peak-load value if load is cyclic).

g = Thermal resistivity of soil (deg C cm/watt).

D = Burial depth of centre line of cable (l in some literature).

Y_i = Distance to centre of cable image from point P in the ground.

Y_c = Distance to centre of cable from point P in the ground.

r = External radius of cable (r_e in some literature).

G_e = External thermal resistance from cable surface to ground surface in deg C per watt/cm. (G_{Ae} = value for cable A).

W_c, W_{sh}, W_a = Conductor, sheath, and armour losses per centimetre respectively, corresponding to total loss of W watt/cm.

G_{ins}, G_s, G_b = Thermal resistance of cable insulation, serving and bedding respectively.

G_i = Equivalent internal thermal resistance of cable, related to total watts loss per centimetre, W. (G_{Ai} = value for cable A).

W_d = Dielectric loss of cable in watts/cm (neglected at 11 kV).

μ = Daily loss load factor of cable current.

F_c = Daily cyclic loading factor of the cable in a specified environment.

G_{BA} = Mutual thermal resistance from cable B to cable A (i.e. external thermal resistance contribution of cable B to the value of G_{Ae} for cable A).

T_c = Temperature rise of cable conductors above ambient (deg C).

T_s = Temperature rise of cable surface, above ambient (deg C).

y = Horizontal centre-to-centre spacing between cables.

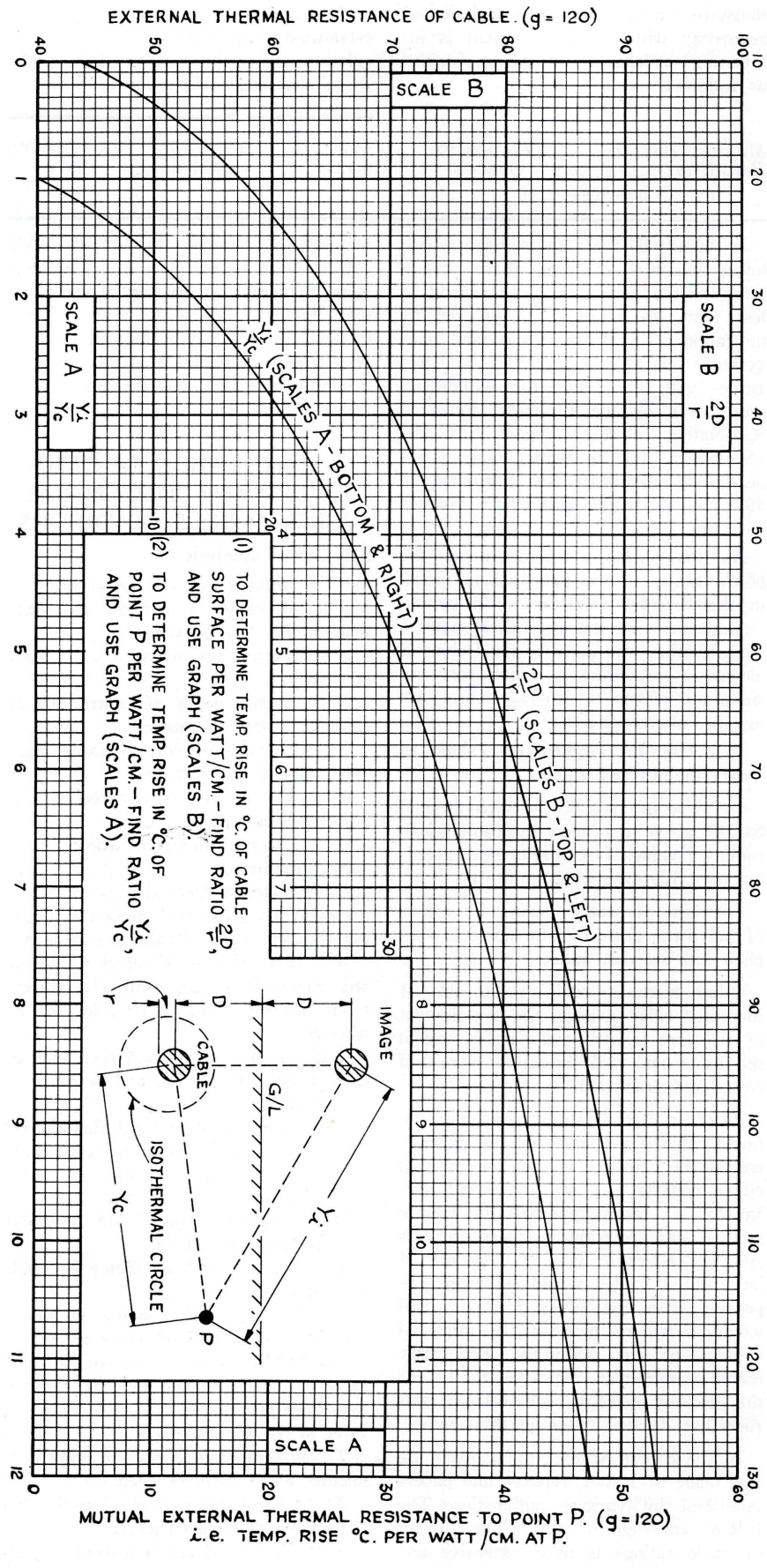

EXTERNAL THERMAL RESISTANCE OF CABLE. (g = 120)
SCALE B
SCALE A
Yi/Yc
2D/r
Yi/Yc (SCALES A - BOTTOM & RIGHT)
2D/r (SCALES B - TOP & LEFT)
(1) TO DETERMINE TEMP. RISE IN °C. OF CABLE SURFACE PER WATT/CM. - FIND RATIO 2D/r, AND USE GRAPH (SCALES B).
(2) TO DETERMINE TEMP. RISE IN °C. OF POINT P PER WATT/CM. - FIND RATIO Yi/Yc, AND USE GRAPH (SCALES A).
r
D
D
CABLE
IMAGE
G/L
ISOTHERMAL CIRCLE
Yc
Yi
P
SCALE A
MUTUAL EXTERNAL THERMAL RESISTANCE TO POINT P. (g = 120)
i.e. TEMP. RISE °C. PER WATT/CM. AT P.

Fig. 2—Graphs for obtaining external thermal resistances (for q = 120°C cm/watt)

W' = The value of W in each cable A, B, C, etc. of a group all carrying the same current I'.

F_g = Group rating factor for steady load conditions.

Fg_c = Combined group and cyclic loading factor.

F_s = Cable surface temperature rise factor.

3.2 Basic principles

(a) In all calculations, the thermal "Ohm's Law" applies, i.e. temperature difference (deg C) = watts × thermal resistance.

(b) For cables, a 1 cm length is considered and W = total watts loss per centimetre of cable.

(c) The soil is assumed to be of uniform thermal resistivity g, and all calculations below are for g = 120 deg C cm/watt. All temperature rises of cable surfaces or other points in the ground are directly proportional to the value of g.

(d) All calculations regarding temperature rise, and distribution of heat flow in the ground are based on the introduction of a cable image above the ground level as shown in Fig. 2. The medium of resistivity g is assumed to be continuous round both cable and image. W watts of heat is assumed to flow outwards radially in all directions from the cable, and W watts is assumed to flow inwards radially to the "image". From this conception it can easily be shown that the temperature rise due to the cable above the ground level isothermal, at any point P distant Y_i from the cable image and Y_c from the cable itself, as shown in Fig. 2, is given by:

$$\text{Temp. rise} = \frac{Wg}{2\pi} \log_e \frac{Y_i}{Y_c} \quad . \quad . \quad . \quad . \quad (1)$$

The temperature rise at the top surface of the cable of external radius r and burial depth D is clearly therefore

$$\frac{Wg}{2\pi} \log_e \frac{2D-r}{r}$$

and at the bottom surface

$$\frac{Wg}{2\pi} \log_e \frac{2D+r}{r}$$

These two temperatures must in practice be nearly the same owing to the equalising effect of the cable sheath isothermal, and the effective value of cable surface temperature rise is given by:

$$\text{Temp. rise} = \frac{Wg}{2\pi} \log_e \frac{2D}{r} \quad . \quad . \quad . \quad . \quad (2)$$

It may therefore be stated that the effective external thermal resistance G_e of the cable is given by:

$$G_e = \frac{g}{2\pi} \log_e \frac{2D}{r} \text{ thermal ohms} \quad . \quad . \quad (3)$$

These formulae (1) and (2) are used in all cable rating calculations, and calculations of group rating factors such as published by the E.R.A. The conception of the two heat sources can also be used to determine the direction and "density" of the resultant heat flow at any point, or the quantity of heat passing through any plane surface parallel to the cable. This can be most useful when considering dimensions for an electrolytic tank.

(e) The other important factor is that the temperature rise at any point P due to any heat source W_A can be added to the temperature rise at P due to any other heat source W_B. This is sometimes referred to as the principle of superposition, and is of great importance in the calculation of group rating factors.

(f) A further factor in the conductor temperature rise is the internal thermal resistance of the cable. If the conductor losses are W_c, the sheath losses W_{sh} and the armour losses W_a, and if the thermal resistance of the insulation is G_{ins}, that of the bedding G_b and that of the serving G_s, then the total temperature rise inside the cable between outer surface and conductor is $W_c G_{ins} + (W_c + W_{sh}) G_b + (W_c + W_{sh} + W_a) G_s$. As W_c, W_{sh} and W_a are all approximately proportional to the square of the current for a given cable, it is possible to assign an equivalent internal thermal resistance G_i, such that the total internal temperature rise as above is equal to WG_i, where $W = W_c + W_{sh} + W_a$ and this procedure is adopted in the examples which follow.

No allowance is made for dielectric losses in the above, and these are insignificant at voltages up to 11 kV. At 33 kV they are small, but at 66 kV and above allowance should be made for them. If expressed as W_d watt/cm, they cause a constant conductor temperature rise $W_d(\frac{1}{2}G_{ins} + G_b + G_s + G_e)$ which can be calculated first, and assumed to reduce the permissible temperature rise by this fixed amount, independent of load.

3.3 Application of the above formula to cable ratings

E.R.A. Report F/T 183 publishes current ratings calculated from the above formulae and also gives curves showing the average grouping factors. As is pointed out in E.R.A. report F/T 187[2], the curves tend to give grouping factors on the high side for cables larger than the average (say 0.1 in^2, 11 kV), and on the low side for depths of burial less than the 3 ft for which the calculations have been made. Although the error is not great, it can in some cases suggest the selection of a cable size larger than that which would suffice, and this could involve a considerable sum of money.

In practice, however, cables laid adjacent to one another are very often of different sizes carrying different load currents, and the temperature rise or current rating cannot then readily be determined from grouping factors.

Another important fact is that nearly all authorities in New Zealand have very considerable daily cyclic variations in the load currents in their cables, but few engineers have the time to study and apply the detailed information given in E.R.A. Report F/T 186[3] when using grouping factors under these conditions. It was partly the realisation of the serious errors due to the writer's earlier calculations for such conditions that led to the preparation of this paper. It is hoped that the procedures set out below may save a great deal of time for those who feel the need to obtain reasonably accurate results.

It should, however, be emphasised that results obtained in practice will vary considerably from the calculated values, owing to, for example:

(i) Variation in the nature of the soil at different depths.

(ii) Variation in moisture content at different depths.

(iii) Inadequate consolidation round cables, leading to formation of voids.

Fortunately, however, cables have considerable inbuilt tolerance, with the result that if the calculations are correct, practical variations are not likely to prove disastrous provided that due allowance is made for conditions known to be specially onerous.

3.3.1. *Suggested procedure*

(a) Take a typical daily load curve and calculate the loss load factor μ as suggested in (a) of Table 8 of E.R.A. Report F/T 186 (i.e. calculate the average value of (cyclic load/peak load)^2 for 24-hourly steps). The daily loss load factor is represented by the symbol μ, and is approximately 0.5 for typical Christchurch loadings. For mutual heating of one cable by another which is 12 in or more away, the average value of cable watts, i.e. μW, can be used with confidence (where W is the peak value).

(b) Calculate the daily cyclic loading factor F_c from the daily load curve for a commonly used size of cable. The procedure is set out in E.R.A. Report F/T 186[3], and it is suggested that the method in example 2a of this report be followed, using the conservative value of 0.02 for

TABLE I—DATA ON THREE-PHASE 11 kV PAPER-INSULATED, BELTED, LEAD-SHEATHED AND ARMOURED CABLE TO BS 480

		Copper conductors		*External thermal resistance (G_e) (or temp. rise of cable surface in deg. C per watt/cm) for $g = 120°C$ cm/watt, at stated depths D to cable centre line (ft)*						*Aluminium conductors*		
Nominal cable size (in^2)	*External diameter* (in)	*Total* W/I^2 at 65° C*	*Equiv. internal thermal resistance (G_i)*	1 ft	1.5 ft	2 ft	2.5 ft	3 ft	3.5 ft	*Equiv. internal thermal resistance (G_i)*	*Total* W/I^2 at 65° C*	*Nominal cable size* (in^2)
0.04	1.68	24.4×10^{-6}	56.9	64.0	71.7	77.3	81.5	85.0	88.0	56.9	39.8×10^{-6}	0.04
0.1	2.01	9.60×10^{-6}	43.9	60.6	68.4	73.9	78.1	81.6	84.6	43.9	15.65×10^{-6}	0.1
0.3	2.57	3.41×10^{-6}	30.2	55.9	63.7	69.2	73.4	77.0	79.9	30.6	5.49×10^{-6}	0.3
0.5	2.99	2.25×10^{-6}	23.7	53.1	60.8	66.4	70.6	74.1	77.0	24.4	3.54×10^{-6}	0.5

* Note—(i) The total watts/cm W includes an allowance for sheath and armour loss, and is calculated for the maximum conductor temperature of 65° C. For any other temperature of $T°C$, the above value of W/I^2 should be multiplied by

$1 + 0.00334\ (T-65)$ for copper, and by
$1 + 0.00342\ (T-65)$ for aluminium.

(ii) Approximate values for W/I^2 for three-phase cables can be obtained by multiplying the standard d.c. resistance for single stranded conductors in ohms/1,000 yd at 20° C by the following factors (values of these factors for other cable sizes can be obtained with sufficient accuracy by interpolation):

	Copper					*Aluminium*				
Size in^2	0.04	0.1	0.3	0.5	*Size in^2*	0.04	0.1	0.3	0.5
Factor	39.6×10^{-6}	39.6×10^{-6}	42.2×10^{-6}	45.9×10^{-6}	*Factor*	39.6×10^{-6}	39.6×10^{-6}	41.5×10^{-6}	44.1×10^{-6}

soil diffusivity. For the typical Christchurch load curve the factor F_c is 1.14 for 0.5 in² cable and 1.09 for 0.04 in² cable—i.e. very close to the figures for intermittent loading, type A, given in E.R.A. Report F/T 183. These figures are for $g = 120$, but slightly lower factors are obtained if $g = 90$.

For conductor temperature rises in a cable owing to its own heating of daily peak value W watts the value W/F_c^2 should be used for the watts loss in calculations. For 0.3 in² cable in soil of $g = 120$ in Christchurch, where F_c is 1.13, this is 0.78 W.

(c) Obtain the equivalent internal thermal resistance G_{Ai} of the cable A concerned from Table I, interpolating if necessary.

(d) Obtain the value of the external thermal resistance G_{Ae} (or temperature rise in deg C per watt/cm of the cable surface) for the size of cable A concerned at the depth of burial to the cable centre line, from Table I. Correct this in direct proportion to the value of g, if this is other than 120 deg C cm/watt. Interpolate if necessary.

(e) Obtain the values of mutual thermal resistance from any other cables B, C, etc. in the same horizontal plane to the cable A under consideration. Call these G_{BA}, G_{CA}, etc. They may be obtained from Table II, by interpolation if necessary, and corrected in proportion for any value of g other than 120. Where cables are in different horizontal planes, reference should be made to paragraphs (k) and (l) below for methods of obtaining the mutual thermal resistance values.

On the assumption that cables B, C, etc. are about 12 in or more away from cable A, the temperature rise T_c of the conductors of cable A is given by

$$T_c = \left[\frac{1}{F_c^2} W_A (G_{Ae} + G_{Ai}) + \mu W_B G_{BA} + \mu W_C G_{CA} + \ldots\right] \text{degC} \quad . . (4)$$

Where W_A is total peak value of loss in watts/cm of cable A, W_B is total peak value of loss in watts/cm of cable B, etc., and μW_B is average daily loss in watts/cm of cable B, etc.

Where the spacing is less than 12 in, a factor with a higher value than μ should be used in the above formula, as suggested in paragraph (m) below.

(f) If the peak values of current are known for all the cables then W_A, W_B, and W_c are obtained for the sizes of cable concerned, from the value of W/I^2 in Table I, and T_c can then be calculated.

Alternatively if W_b and W_c are known, then W_A can be obtained for the maximum permissible value of T_c, and converted into a current value from the value for W/I^2 in Table I.

(g) If all cables carry the same current, and are of the same size then $W_A = W_B = W_C = W'$, and a combined group and cyclic rating factor F_{gc} can be assigned to give the permissible current relative to that permitted for a single cable with a constant current. All thermal resistances are to the central (hottest) cable, and the rating factor is worked out for this cable.

Now for one cable $T_c = W(G_{Ae} + G_{Ai})$, where W = steady rated watts, at the rated current I, giving the rated temperature rise T_c.

And for the group, with cyclic loading,

$$T_c = W'\left[\frac{1}{F_c^2}(G_{Ae} + G_{Ai}) + \mu G_{BA} + \mu G_{CA} + \ldots\right]$$

Clearly for the same temperature rise, the permissible watts varies inversely as the total thermal resistance.

Thus

$$\frac{W'}{W} = \frac{G_{Ae} + G_{Ai}}{\frac{1}{F_c^2}(G_{Ae} + G_{Ai}) + \mu G_{BA} + \mu G_{CA} + \ldots}$$

or

$$F_{gc} = \frac{I'}{I} = \left[\frac{G_{Ae} + G_{Ai}}{\frac{1}{F_c^2}(G_{Ae}+G_{Ai}) + \mu(G_{BA}+G_{CA}+\ldots)}\right]^{\frac{1}{2}} \quad . . . . (5)$$

This may also be written in the form:

$$F_{gc} = \left[\frac{1}{F_c^2} + \frac{\mu(G_{BA}+G_{CA}+\ldots)}{G_{Ae}+G_{Ai}}\right]^{-\frac{1}{2}} \quad . . . . (6)$$

(h) The group rating factors given in E.R.A. Report F/T 183 are for steady load, where F_c and μ are both unity; hence if F_g represent this factor, then from equation (6) above,

$$F_g = \left[\frac{1}{1 + \frac{G_{BA}+G_{CA}+\ldots}{G_{Ae}+G_{Ai}}}\right]^{\frac{1}{2}} \quad . . (7)$$

Group rating factors for 3 ft depth in soil of $g = 120$ worked out from this formula agree closely with the E.R.A. curves for 0.1 in² cable, which is evidently about the mean size of cable for which the curves are drawn. Note, however, that the E.R.A. curves are drawn for 3 ft "cover" over the top of the cable, whereas the data set out here is for depths measured to the cable centre line.

For example—consider 11, 0.1 in² cables at depth 3 ft to cable centre line and uniform horizontal spacing of 12 in (centre to centre) :

From Table 1, $G_{Ae} + G_{Ai} = 81.6 + 43.9 = 125.5$

And from Table II, $G_{BA} + G_{CA} + \ldots$ etc. summated for cables on both sides of the central cable is

$2(34.5 + 21.95 + 15.35 + 11.24 + 8.52) = 183.12$

$$\therefore F_g = \left[\frac{1}{1 + \frac{183 \cdot 12}{125 \cdot 5}}\right]^{\frac{1}{2}} \text{ from equation 7}$$

TABLE II—MUTUAL THERMAL RESISTANCE BETWEEN CABLES IN HORIZONTAL FORMATION IN GROUND OF UNIFORM RESISTIVITY ($g = 120$ deg C cm/watt)

(i.e. temperature rise in deg C at one cable owing to 1 watt/cm in other cable at stated horizontal distance y.)

*Depth**	*Distance between cables (ft)*														
ft	0.5	1.0	1.5	2.0	2.5	3.0	4.0	4.5	5.0	6.0	7.5	8.0	9.0	10	12
1	27.1	15.35	9.75	6.63	4.73	3.51	2.13	1.72	1.42	1.01	0.66	0.58	0.45	0.38	0.26
1.5	34.5	21.95	15.35	11.24	8.52	6.63	4.27	3.51	2.94	2.13	1.42	1.26	1.01	0.83	0.58
2.0	39.8	27.1	20.0	15.35	12.11	9.75	6.63	5.57	4.73	3.51	2.39	2.13	1.72	1.42	1.01
2.5	44.1	31.1	23.8	18.90	15.35	12.70	8.99	7.71	6.63	5.04	3.51	3.15	2.57	2.13	1.52
3.0	47.5	34.5	27.1	21.95	18.25	15.35	11.24	9.75	8.52	6.63	4.73	4.27	3.51	2.94	2.13
3.5	50.4	37.3	29.8	24.7	20.8	17.8	13.4	11.7	10.35	8.21	5.99	5.44	4.52	3.81	2.80

* To cable centre line

$= 0.638$ (as compared with 0.63 from the E.R.A. curves).

Note, however, that the same calculation for 0.5 in^2 cables gives

$F_g = 0.59$.

(i) If the ordinary group rating factor F_g is known for a group of cables, and μ and F_c are known for cyclic loading, then the combined group and cyclic loading factor F_{gc} is *not* the product F_gF_c. From equation (7)

$$\frac{G_{BA}+G_{CA}+\ldots}{G_{Ae}+G_{Ai}} = \frac{1}{F_g^2} - 1$$

Substituting this in equation (6), the combined factor

$$F_{gc} = \left[\frac{1}{\frac{1}{F_c^2} + \mu\left(\frac{1}{F_g^2} - 1\right)}\right]^{\frac{1}{2}} \quad \ldots (8)$$

Example

Nine 0.04 in^2 11 kV cables at 1 ft 6 in depth, and 1 ft 6 in horizontal spacing.

$F_c = 1.09$, $1/F_c^2 = 0.842$ and $\mu = 0.5$ (for Christchurch M.E.D. load curve)

From Table II, $G_{BA} + G_{CA}$ etc.

$= 2(15.35 + 6.63 + 3.51 + 2.13)$

$= 55.24$

From Table I, $G_{Ae} + G_{Ai}$

$= 71.7 + 56.9 = 128.6$

From equation 7, $F_g = 0.835$ (note mean E.R.A. curve gives 0.72)

From equation 8, $F_{gc} = 0.973$.

Hence the overall grouping and cyclic loading factor is 0.973. The product of the correct grouping factor F_g and the cyclic loading factor F_c is 0.91, an error of 6½%. However, if the grouping factor figure from the mean E.R.A. curve of 0.72 had been used, the product of this and the cyclic loading factor would have been 0.785 instead of 0.973, an error of over 19%.

(j) *Graphical method of obtaining external resistance G_e.*

Where interpolation between the figures of Table I, as suggested in paragraph (d) above, is considered inadequate, the external thermal resistance for $g = 120$ can be read off the appropriate curve of Fig. 2, after the value of $2D/r$ has been calculated. In practice it may be considered just as easy (and more accurate) to find the natural logarithm of $2D/r$ on a slide-rule log-log scale. and multiply this by $120/2\pi = 19.1$ to obtain $G_e = 19.1 \log_e (2D/r)$.

(k) *Graphical method of obtaining mutual thermal resistance.*

Quite a satisfactory way is to mark the cable positions and images on a sheet of graph paper, then measure Y_i and Y_e as shown in Fig. 2 to any suitable scale to obtain the ratio Y_i/Y_e for each cable of the group to the point P where

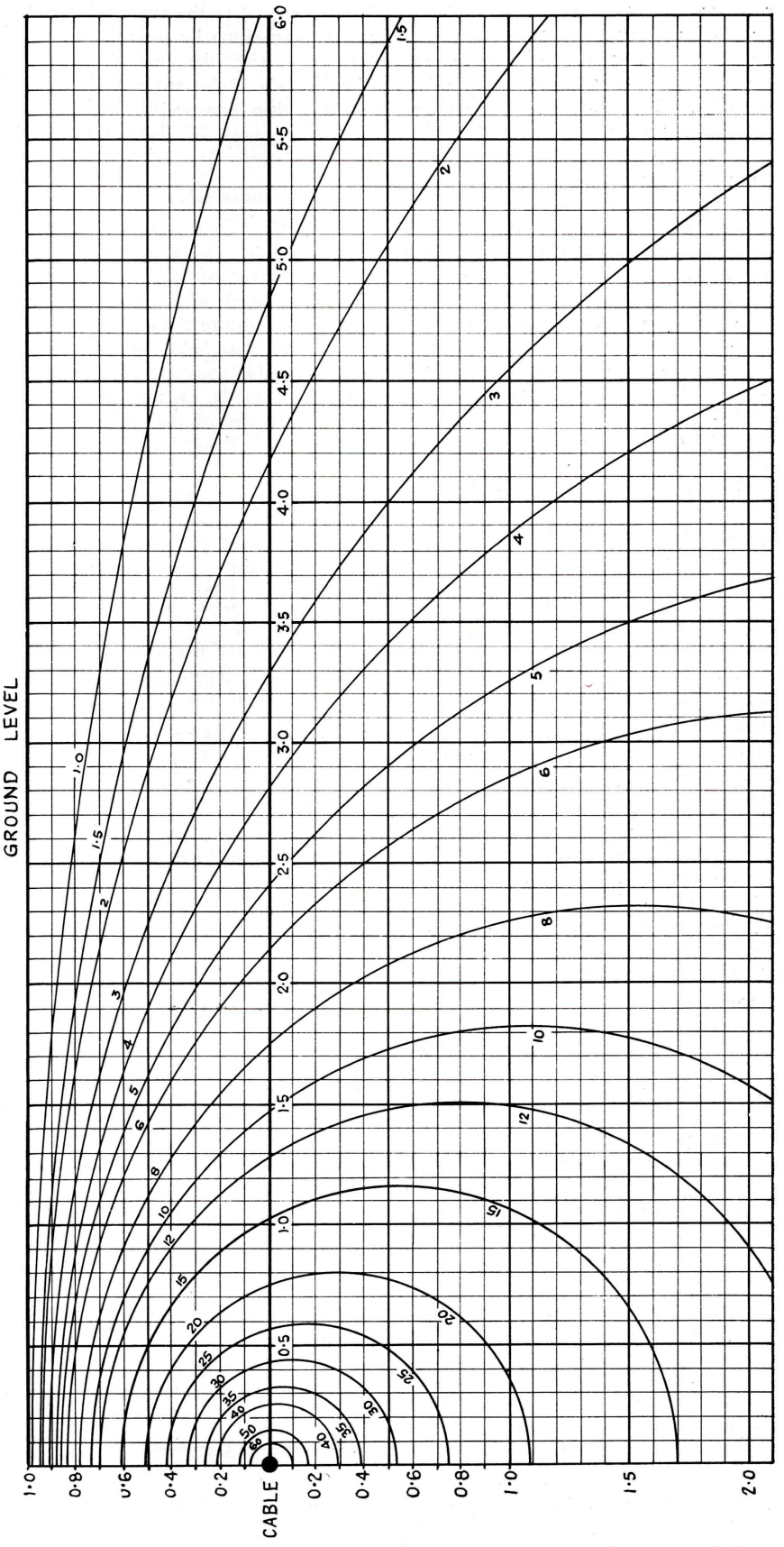


Fig. 3—Isothermals round a heated cable (i.e thermal resistance lines) deg C rise for 1 watt/cm for g = 120° cm/watt

All dimensions are relative, on basis D = 1.0 (where D = cable depth)

the cable A whose temperature rise is being considered is located.

The mutual thermal resistance can then be obtained from the appropriate curve on Fig. 2, or alternatively calculated on a slide rule as 19.1 $\log_e (Y_i/Y_e)$.

It is recommended that all such calculations involving mutual heating between cables be based on cable centre-to-centre measurements. It is only when two cables A and B are nearly touching, that the thermal resistance G_{BA} is a little higher than that obtained as above. Even in this case, however, the error is approximately balanced by the fact that the proximity of the heat-conducting sheath or armour on the adjacent cable B produces a comparable reduction in the external thermal resistance G_{Ae} of cable A. These effects have been checked in an electrolytic tank.

(l) *Alternative graphical method* of obtaining the temperature rise at any point in the ground adjacent to a heated cable (i.e. "mutual thermal resistance").

Figure 3 is extremely useful in determining temperature rises. These curves show the isothermals for $W = 1$ watt/cm, and all measurements are on the basis that the cable depth $D = 1.0$. The temperature rise, which can be found reasonably accurately by visual interpolation, is the mutual thermal resistance from the cable to the point. It is, of course necessary to change the scale if heating from two cables at different depths D is being checked. The point considered is normally the centre of another cable whose temperature rise is being determined.

Example:

Find the temperature rise at a point A 3 ft away horizontally from and 6 in below a cable B which is 2 ft below the ground. Divide the measurements by $D = 2$, so that the point required is 1.5 horizontally from, and 0.25 below, the cable at the origin (in relative units of length). The temperature rise is seen to be 11 deg C per watt/cm. (Note that the calculated value of the mutual thermal resistance is 11.05).

Figure 3 is also useful in calculations involving the quantity of selected backfill required above or below a cable to ensure that the temperature rise does not exceed a certain value in the soil surrounding the backfill.

It is interesting to note that the isothermals are circles. The lines representing heat flow are also circles passing through the cable with centres on the earth's surface and these always intersect each isothermal at right angles. The quantity of heat flowing between any two such heat-flow circles for a given cable is proportional to the angle subtended at the cable position by their points of intersection with the ground level line. For example, if this angle is 15° or $\pi/12$ radians, then one-twelfth of the total amount of heat W flows between the two lines.

(m) *Precaution when calculating sheath temperature rises.*

In paragraph (b) above, it was noted that the value of cable watts W/F_c^2 should be used when calculating conductor temperature rises due to a cable's own cyclic load. As no allowance is made for the thermal capacity of the cable itself in the calculation of F_c, the temperature rise of the cable surface at the peak load W will be:

$$\frac{1}{F_c^2} W(G_e+G_i) - WG_i = W\left[\frac{1}{F_c^2}(G_e+G_i) - G_i\right] \quad \ldots (9)$$

i.e. the conductor temperature rise minus the internal temperature rise. Alternatively, equation (9) may be rewritten:

$$\text{Surface temp. rise} = \left[\frac{1}{F_c^2} - \frac{G_i}{G_e}\left(1 - \frac{1}{F_c^2}\right)\right] WG_e \quad \ldots (10)$$

Although the multiplier

$$\left[\frac{1}{F_c^2} - \frac{G_i}{G_e}\left(1 - \frac{1}{F_c^2}\right)\right]$$

contains terms F_c and G_e which vary with soil resistivity and depth of cable laying, the overall value is found to vary little for a given size of cable as the changes tend to cancel out. If this factor is F_s then the value of watts used in direct calculations of surface temperature rise is F_sW.

Example

For a 0.3 in² cable in soil of $g = 120$ at depth 3 ft.

$G_i/G_e = 30.2/77$

$= 0.39$ (From Table I)

and $F_c = 1.13$ (for Christchurch load curve).

$\therefore 1/F_c^2 = 0.785$

$\mu = 0.5$ (for Christchurch load curve).

$$\therefore \frac{1}{F_c^2} - \frac{G_i}{G_e}\left(1 - \frac{1}{F_c^2}\right)$$

$= 0.785 - 0.39(1 - 0.785)$

i.e. $F_s = 0.70$.

Hence for conductor temperature use W/F_c^2 ($= 0.785\,W$ in above case); for surface temperature rise use F_sW ($= 0.70\,W$ in above case); for temperature 12 in or more away use μW ($= 0.5\,W$ in above case).

It may be assumed that a value between 0.5 and 0.7 may be used for temperatures at points less than 12 in away from the above cable.

4. WATER COOLING OF CABLES

A study was made of the effect of cooling a cable by means of an adjacent water pipe, which in practice would probably be 2 in diameter polythene pipe. This size of pipe can be obtained at a reasonable price in the form of coils, so that laying would be quite a simple operation. The method is particularly suited to Christchurch conditions where artesian water can be obtained readily with little risk of failure. It becomes less attractive if means are required to cool the water.

In practice, it may be necessary to use only a trickle of water (or none at all) under normal conditions, reserving the cooling for emergency conditions when, for example, a failure of one cable causes an increased load in other cables. It is understood that this principle has been adopted in Canada.

Although there have been a number of papers written on water-cooling, only one giving a formula for calculating the cooling effect could be located, and it is not considered that this gives an accurate solution.

A study of the problem indicated that watts of heat extracted by a cooling pipe could be treated by the same method of "superposition" as is adopted for watts added by heating from another cable. The important difference is, however, that the watts extracted by the pipe is not a fixed quantity, but is dependent on the temperature of the water in the pipe, which increases along the route of the cooled cable.

Formulae are developed below based on the "mutual thermal resistances" referred to earlier. These mutual resistances can be calculated reasonably accurately provided that the pipe is not too close to the cable. It is assumed, however, that the pipe surface will be at least 1 in from the cable surface, in order to ensure that soil is packed well round the cable, and a check in the electrolytic tank indicates that the error at this spacing would not exceed 2% even without serving over the armour or sheath, and this is not serious. It is assumed that there is one pipe beside each cable, where there is more than one cable, and the resulting cable/pipe

groups are numbered 1, 2, 3, 4, etc., the numbers being used as suffixes to the symbols. The symbols used are:

W = watts/cm dissipation of a single cable (e.g. W_1, W_2, etc.).

G_e = external thermal resistance of a single cable.

W_p = heat flow from ground to pipe.

G_e' = external thermal resistance of a single pipe.

G_i = equivalent internal thermal resistance of a cable.

G_i' = internal thermal resistance of a pipe (i.e. the pipe wall).

G_{cp} = mutual thermal resistance from cable to pipe.

G_{pc} = mutual thermal resistance from pipe to cable.

G_{21}' (or G_{p2p1}) = mutual thermal resistance from pipe 2 to pipe 1 and

G_{21} (or G_{c2c1}) = mutual thermal resistance from cable 2 to cable 1.

ϕ = water temperature rise at any point (general symbol).

T_w = temperature rise of water in pipe at distance L from start of cable route (T_{w1}, T_{w2}, etc.).

θ = initial water temperature rise above ground ambient (generally about zero).

t = time in seconds.

T_s = cable surface temperature rise (e.g. T_{s1}, T_{s2} for cables 1 and 2).

T_c = cable conductor temperature rise.

Q = water flow in pipe (cubic-centimetres/second).

L = distance from start of cable route (cm).

$$\alpha = -\frac{L}{4{\cdot}18Q(G_i'+G_e')}$$

(adopted for convenience).

Note: exp $(-x)$ means e^{-x} in the following formulae.

4.1 Formula for single cable and pipe

The following important formula is developed in the appendix to give the cable conductor temperature rise for a single cable cooled by a single adjacent pipe, where the initial water temperature is the ambient temperature:

$$T_c = W\left[G_e+G_i-\frac{G_{cp}\,G_{pc}}{G_i'+G_e'} \times \exp\left(-\frac{L}{4{\cdot}18\,Q(G_i'+G_e')}\right)\right] \quad \ldots\ldots (11)$$

Note: (i) $G_{cp} = G_{pc}$ if cable and pipe are at the same level. If the pipe and cable are very close together, and are of different sizes, they will not be exactly equal. They should be calculated as described earlier in Section 3.3.1 (k) for cables.

(ii) It will be seen that for given cable and pipe constants the temperature rise is dependent on the ratio Q/L, i.e. the ratio of water flow to length of route. Note that cooling of 1 gal/min per 1,000 yd route length gives a value of 0.000828 for Q/L or of 1,209 for L/Q in the above formula.

(iii) The external thermal resistance of the pipe G_e' is calculated exactly as described earlier in Section 3.3.1 (j) for cables. The internal thermal resistance G_i' based on a resistivity of 400 for polythene, is $(400/2\pi)\log_e(r_e/r_i)$ thermal ohms, where r_e is the external radius of the pipe and r_i the internal radius. For a 2 in bore pipe of thickness 0.125 in the value of G_i' is therefore 7.5 thermal ohms.

(iv) Similar formulae for heat flow to the pipe, and water temperature rise are also developed in the appendix.

4.2 Formula for two cables and pipes

If there are two cable pipe groups as above arranged in a *symmetrical* manner, with the cables having the same dimensions and value of W, and the pipes the same dimensions and flow of water Q, then it is evident that the heat flow to one pipe is equal to the heat flow to the other pipe. In these circumstances it can be shown that the above formula, and the others calculated in the appendix, are still correct if the following substitutions are made:

(i) For G_e, put $G_e + G_{c2c1}$
(ii) For G_{cp}, put $G_{c1p1} + G_{c2p1}$
(iii) For G_{pc}, put $G_{p1c1} + G_{p2c1}$
(iv) For G_e' put $G_e' + G_{p2p1}$

There is of course no change in G_i or G_i'.

4.3 Formulae for more than two cables and pipes

The development of a formula to cover this condition is extremely difficult as it is no longer possible to obtain complete symmetry. As a result, the temperature rises and heat flows to the pipes will be different, and the values of W_{p1}, W_{p2}, W_{p3}, etc. cannot readily be obtained, as they are all interdependent.

As the practical case being studied involved up to 12 cables, with one cable loaded to a much higher value of W than the others, the only practicable method of calculation was a laborious step-by-step one for each pipe, using quite small steps. It was decided therefore to study this case in an electrolytic tank.

4.4 Practical case with pipe nearly touching cable

As the mutual thermal resistance between cable and pipe could not be calculated with any degree of certainty for close spacing (say less than one inch), it was considered that this condition could also best be studied in the electrolytic tank.

4.5 Conclusions re water cooling

The calculations indicated that quite useful cooling could be obtained in this way, and would enable high emergency overload currents to be carried. The difficulties are of a practical nature, such as availability of a reliable source of water, a suitable place to dispose of the water, and supervision to ensure that it will be operative when required.

The cooling is still more effective if the cable is placed inside a larger pipe with water flowing round the cable, although the installation is much more difficult to carry out. On the assumption that the water is in motion, then the inside of the pipe, the water and the cable surface may all be assumed to be at the same temperature. The same formulae then apply as before, but G_e, G_{cp} and G_{pc} are all equal to the total pipe thermal resistance $(G_i' + G_e')$.

Another way of water cooling is the so called "irrigation" method, whereby a steady trickle of water is released from a porous or perforated pipe above the cable. This not only cools but also keeps down the value of external thermal resistance. The difficulty is in ensuring a uniform continuous release of water, at a rate which is fairly critical if water-logging of the ground is to be avoided. The possibility of making a slightly porous plastic pipe which would stand a fairly high water pressure was explored without success, but this might be a solution.

Acknowledgements

The writer acknowledges the assistance received from colleagues at the Christchurch M.E.D., particularly from R. D. Spence, who designed the electrolytic tank and also carried out site investigations.

Note.: The appendix and references are given overleaf.

APPENDIX

DEVELOPMENT OF FORMULAE FOR WATER COOLING

(See Section 4 of paper for description and list of symbols)

1. Single cable and pipe:

(a) *Relation for fixed water temperature rise.*

The temperature rise in the ground at the pipe position due to cable watts W, assuming no pipe cooling, is WG_{cp} deg C where G_{cp} is calculated as described earlier.

Hence the temperature difference between the ground and the water is $(WG_{cp}-\phi)$ deg C. This must cause a flow of heat W_p from the ground to the pipe such that:

$$(WG_{cp}-\phi) = W_p(G_i' + G_e')$$

$$W_p = \frac{WG_{cp} - \varphi}{G_i' + G_e'} \quad \ldots . \text{(i)}$$

Temperature drop at cable owing to this heat flow W_p

$$= W_p G_{pc}$$

$$= \frac{WG_{cp} - \varphi}{G_i' + G_e'} G_{pc} \quad \ldots . \text{(ii)}$$

Hence cable surface temperature rise is given by

$$T_s = WG_e - \frac{WG_{cp} - \varphi}{G_i' + G_e'} G_{pc} \quad \ldots \text{(iii)}$$

(b) *Water temperature rise along cable route.*

Consider a small element of water of length dL and volume dV moving at constant velocity down the pipe.

The watts of heat flowing into this element dL are $W_p dL$.

$\therefore$ Temperature rise of element

$$d\varphi = \frac{(W_p\, dL)\, dt}{dV\,(4{\cdot}18)} \text{ degC}$$

$$= \frac{W_p\, dL}{4{\cdot}18Q} \text{ degC}$$

where $Q = dV/dt$ cc/s.

Substituting the value of W_p from equation (i),

$$d\varphi = \frac{WG_{cp} - \varphi}{(G_i' + G_e')\,4{\cdot}18\,Q} dL \text{ degC}$$

$$dL = 4{\cdot}18\,Q\,(G_i' + G_e')\frac{d\varphi}{WG_{cp} - \varphi}$$

$$\therefore \quad L = 4{\cdot}18\,Q\,(G_i' + G_e')\,[-\log_e(WG_{cp} - \varphi)]_{\theta \text{ to } T_w}$$

$$= 4{\cdot}18\,Q\,(G_i' + G_e') \times \log_e \frac{WG_{cp} - \theta}{WG_{cp} - T_w} \quad \ldots . \text{(iv)}$$

$$\therefore WG_{cp} - T_w = (WG_{cp} - \theta)\exp\left(-\frac{L}{4{\cdot}18Q(G_i' + G_e')}\right) \quad \ldots . \text{(v)}$$

For convenience we shall now introduce the symbol α defined as

$$\alpha = -\frac{L}{4{\cdot}18Q(G_i' + G_e')}$$

Hence the water temperature rise T_w at distance L from the position where the temperature rise was θ is given by:

$$T_w = WG_{cp} - (WG_{cp} - \theta)\exp\alpha \quad \ldots . \text{(vi)}$$

or

$$T_w = WG_{cp}(1 - \exp\alpha) + \theta\exp\alpha \quad \ldots . \text{(vii)}$$

If the initial temperature rise θ is zero, this is:

$$T_w = WG_{cp}(1 - \exp\alpha) \quad \ldots . \text{(viii)}$$

(c) *Heat flow to the pipe along cable route.*

This is given by equation (i) where ϕ is now T_w. Substituting the value of $(WG_{cp} - T_w)$ from equation (v) for $(WG_{cp}-\phi)$ in equation (i), we have

$$W_p = \frac{(WG_{cp} - \theta)\exp\alpha}{G'_i + G_e'} \quad \ldots . \text{(ix)}$$

(d) *Cable temperature rise along cable route.*

The temperature rise T_s of the cable surface is given by equation (iii) where ϕ is now T_w. Hence substituting $(WG_{cp} - T_w)$ from equation (v) for $(WG_{cp}-\phi)$ in equation (iii), we have

$$T_s = WG_e - \frac{(WG_{cp} - \theta)\,G_{pc}}{G_i' + G_e'}\exp\alpha \quad \ldots . \text{(x)}$$

If the initial temperature rise θ is zero, this is:

$$T_s = W\left(G_e - \frac{G_{cp}G_{pc}}{G_i' + G_e'}\exp\alpha\right) \quad \ldots . \text{(xi)}$$

and the conductor temperature rise T_c is given by

$$T_c = W\left(G_e + G - \frac{G_{cp}\,G_{pc}}{G_i' + G_e'}\exp\alpha\right) \quad \ldots . \text{(xii)}$$

References

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2 E.R.A. Report F/T 187: The calculation of continuous current ratings and rating factors for transmission and distribution cables.

3 E.R.A. Report F/T 186: Methods for the calculation of cyclic rating factors and emergency loading for cables laid direct in the ground or in ducts.

4 E.R.A. Report F/T 192: The calculation of external thermal resistance and cyclic rating factors for groups of cables laid directly in the ground or ducts.

5 E.R.A. Report F/T 204: Field tests on thermal properties of soil and their effects on cable ratings.

6 E.R.A. Report F/T 181: Methods of determining thermal resisitivity of soil in situ for the calculation of cable ratings.

7 E.R.A. Report F/T 193: The structure of the soil and a critical review of the mechanisms of soil moisture retention and migration.

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ADDENDUM

SINCE preparing the paper, the writer has confirmed the value of the set of isothermal curves devised in Fig. 3. They were found to be very useful for checking the amount of selected thermal backfill required round the 66 kV cables in the Bromley area to ensure that the temperature in the surrounding sand did not exceed 30°C. A graded sand bound with cement (14/1 sand-cement) was used for this backfill, and the use of Fig. 3 made it evident that considerably less of it was required than had been proposed—with the obvious result that the cost was greatly reduced.

As the results obtained depend on the load curve used, the typical M.E.D. load curve referred to in the paper, and used for the Bromley calculations, is given in Table I.

The important loss load factor μ, which is the average of the watts-loss figures given above, is just under 0.5, and this value has been used in all calculations.

The calculations have also been based on an assumed conservative value of soil thermal diffusivity of 0.2 cm²/sec, as recommended by the E.R.A., where further information is not available. Recent field measurements indicate, however, that the value for Bromley sand with about 6% moisture content is approximately 0.01 cm²/sec.

Using the method outlined in section 2.4 and example 2a of E.R.A. Report F/T 186, it is found that the maximum conductor temperature is obtained a short time (about half an hour) after the peak-load value at 17.00 hours Y0 to Y5 then having the values shown in Table I. The term (B + μd) in the cyclic rating formula given in F/T 186 then has a value of 0.68 for the 3½ in diameter 66 kV cable and this is the important cable surface temperature rise factor "*Fs*" referred to in the paper. Although it was shown that this factor can be calculated if the cyclic loading factor *Fc* of the cable is known, this is clearly merely reversing the steps followed in calculating the value of the cyclic loading factor. The sheath temperature rise is equal to $Fs(WGe)$ where W is the peak value of watts loss/cm.

The above surface factor *Fs* is a particular case of the general factor *Cs* which can be calculated for points in the soil at any given distance from the centre of a cable whose heating effect is being studied, the formula for *Cs* being given in equation 16 of E.R.A. report F/T 192; this report also contains the information required to enable the calculation to be carried out. Table II given below gives calculated values of *Cs* for different distances from a cable with the Christchurch load curve and soil diffusivity = 0.02 cm²/sec; note that in the case of the 6 in and 12 in calculations, a total time T of 24 hours was considered, instead of six hours.

TABLE I

Time (hours)	*Load relative to max. load*	*Watts loss relative to max. value*
01.00	0.302	0.091
02.00	0.261	0.068
03.00	0.217	0.047
04.00	0.195	0.038
05.00	0.195	0.038
06.00	0.326	0.106
07.00	0.695	0.484
08.00	0.892	0.794
09.00	0.848	0.719
10.00	0.826	0.681
11.00	0.784	0.612
12.00	0.805	0.646 (Y5)
13.00	0.826	0.681 (Y4)
14.00	0.760	0.579 (Y3)
15.00	0.760	0.579 (Y2)
16.00	0.848	0.719 (Y1)
17.00	1.000	1.000 (Y0)
18.00	0.956	0.914
19.00	0.935	0.873
20.00	0.914	0.832
21.00	0.783	0.611
22.00	0.653	0.425
23.00	0.521	0.272
24.00	0.348	0.121

TABLE II

Distance from cable centre (in)	*Cs at time of max. conductor temp.* (i.e. ½ hour after peak load)	*Max. value of Cs*	*Time at which Cs is a maximum* (hours after peak load)
1¾ (cable surface)	0.68	0.685	1½
3	0.63	0.655	3
6	0.55	0.60	4
12	0.50	0.54	6

Notes:

(i) The maximum value of *Cs* (giving the maximum temperature at the point in the soil considered) occurs generally later than the maximum conductor temperature.

(ii) The value of *Cs* used to determine the increase in conductor temperature owing to mutual heating from an adjacent cable is given in column 2. Note that this is equal to μ (i.e. 0.5) at a distance of 12 in.

(iii) For a soil diffusivity of 0.1 cm²/sec, the values of *Cs* are all lower than the corresponding values above, and the maximum values occur later.

(iv) Although the above values are calculated for the Christchurch load curve, they will give a rough guide to the approximate values to be assumed for other load curves which are of this general shape, with a loss load factor of approximately 0.5.

Example showing calculation of temperature rise at boundary of backfill (using Fig. 3)

Take the case of seven cables, each 3½ in diameter, laid at a depth of 30 in to the cable centres, and at 12 in horizontal spacing in soil of $g = 120$. Assume the M.E.D. load curve (μ = 0.5) with peak watts/cm in each cable (W) of 0.25. Ambient temperature = 15°C.

Assume the centre cable (the hottest) to be at the cable position shown in Fig. 3. The three cables on one side will be at scale positions 0.4, 0.8 and 1.2, since the scale is 30 in = 1.0. Mark these positions at cable level, and also at the points 6 in (i.e. 0.2) and 12 in (i.e. 0.4) above these positions. Read off the approximate rises at these points for a steady value of W = 1.0 W/cm (interpolating between curves).

Deduce approximate values of *Cs* for each distance from the cable under consideration, from the above table, interpolating where necessary. For distances greater than 12 in the value of *Cs* is assumed to be equal to μ (i.e. 0.5). The results can be written down rapidly as follows, where $W = 0.25$:

(a) *At surface of middle cable.* (Note that $Ge = 68.7$)

Maximum temperature (°C)
= 15+0.25 [0.685×68.7+2 (0.51 × 31.5 +0.5×19+0.5×13.5)]
= 15+27.9
= 43°C (approx.)

(b) *At point 6 in above middle cable centreline.*

Maximum temperature (°C)
= 15+0.25 [0.6×42+2 (0.53×27.5+0.5 ×16.5+0.5×11)]
= 15+20.4
= 35.4°c (approx.)

(c) *At point 12 in above middle cable centreline.*

Maximum temperature (°C)
= 15+0.25 [0.54×26.5+2 (0.52×20+ 0.5×13.2+0.5×8.8)]
= 15+14.3
= 29.3°C (approx.)

If it is desired to keep the temperature down to about 30°C in the natural sand, then the selected backfill must extend to a level of approximately 12 in above the centreline of the middle cable in the above example. If the thermal resistivity of the selected backfill is also of the order of 120, then the calculated temperature rises will not be affected by the introduction of this material.

Discussion

I. A. McCutcheon (Wellington M.E.D.)—Mr Johnstone is faced with a problem resulting from the need to lay a large number of 66 kV underground cables through areas of sandy soil of uniform particle size and where the moisture retentivity is poor. This in turn causes wide variations in the soil thermal resistivity.

The method of using the principle of superposition to find the mutual thermal resistance between cables, and thus the cable temperature, is perhaps of more value than the grouping factors developed in E.R.A. report F/T 183. However, because of the usual variation in moisture content and the lack of homogeneity in the soil, I question whether the methods developed by Mr Johnstone are really of much greater value than using the established E.R.A. factors.

Mr Johnstone postulates that the thermal problems associated with cables passing through unreliable soil might be solved by the use of (a) low-thermal-resistivity bedding and backfill material which has a low value irrespective of moisture content; or, (b) artificial cooling by means of water cooling pipes laid alongside the cables and acting as a heat sink for heat generated in the cable.

In my opinion the method (a) of ensuring satisfactory cable thermal performance, particularly for 66 kV cables, would appear to be a much more reliable method than (b) and certainly, long-term, a more economic proposition. Mr Johnstone has not mentioned the relative economies of either of these alternatives and I would ask whether he has done any work on this aspect and if so, what were the comparative costs?

With respect to artificial cooling, Mr Johnstone has developed relationships, again based on the principle of superposition, for finding the effective temperature along the artificially-cooled underground cable in terms of the configuration, the thermal resistivity and the rate of flow of the cooling water along the pipe. The greatest cable cooling will be at the feed-in point of the cooling water and the rise of temperature along the cooled cable will be exponential as pointed out by Mr Johnstone. It would appear that a better hypothetical case could be made out for feeding cooling water in both directions along the cable. Did Mr Johnstone consider this?

One point with respect to the artificial cooling of cables by adjacent pipes, which would worry me greatly, is that the soil between the cable and the cooling pipe can dry out, causing greatly reduced heat flow to the cooling pipe. As is well known, it is the very high thermal resistivity soil in the immediate vicinity of the cable that causes thermal runaway.

Considering this point, does Mr Johnstone think that artificial cooling of cables is really of great value? Has it been seriously considered or was it a comparatively early decision to use low-thermal resistivity bedding and backfilling material when there was doubt regarding the thermal stability of the cable?

He has made no mention of the use of thermocouples and I would ask whether he considers it advisable to supervise the 66 kV cables thermally by means of thermocouples and pilots at points where the cable performance may be in doubt. There are also practical difficulties in the laying of flexible plastic polythene pipes in the ground, such as jointing and ensuring rigidity. I would be pleased to have Mr Johnstone's comments on these points.

R. G. S. Powell (Waitaki E.P.B.)—The Christchurch M.E.D have planned a long way ahead for the future development of Christchurch. Their present loading is about 200 MW, or a little more, yet an ultimate load of 1,000 MW from this one substation alone is mentioned.

We know that the difficulties involved in bringing large blocks of power to cities are considerable, particularly by underground cable. In the United Kingdom recently tests of running cables down canals were carried out, in which a canal route was chosen as the ideal place in which to run h.v. cable. Has Mr Johnstone thought of this possibility? The river Avon could be quite handy!

The value of g of 120, which is taken in the paper, and on which all calculations are based, is said to be a standard figure. Overseas they talk of g as being as low as 30 and 40, which is considerably less.

Mr Johnstone's particular conditions, very uniform sand drains, are among the worst possible.

Mr Spence's paper deals with piping and cable technique, whereas Mr Johnstone's paper stated a preference for the selected backfill. Perhaps he could state why they studied the cable and pipe technique to such a great extent in this electrolytic tank.

M. G. Keys (Auckland E.P.B.)—The Bromley sand which gave rise to this investigation is not peculiar to Christchurch. We have been following a practice recommended by manufacturers in Britain of laying our supertension gas-pressure, oil-filled cables in sand. We have several very major feeds laid in this way, and having read the alarming results that Mr Johnstone has found of over 212°F sheath temperature, we had an analysis made of the sand used to bed these super-tension cables. It is identical with Bromley sand.

The proposed backfill is presumed, I gather, to have a g of 120, and there are no water pipes to be used. If so, the amount of water flowing was sufficient. But the ultimate criterion is that of cable sheathing, and even with the backfill in this important section of cable, Mr Johnstone will not really know whether the cable is going to be down to the figure he wants or not. I make a suggestion—and we are currently investigating this in Auckland—that he should consider the installation of thermocouples on the sheaths of the cables (particularly over the centre cables in the raft) at periodic intervals along the cable run and take these thermocouples up to an above-ground marshalling point. From this point he can, from time to time, take readings which will clearly give him the answer he really wants—what is the temperature of the cable sheath?

The real question, however, despite all the research Mr Johnstone carried out, is still, to quite a degree, unsolved.

I feel he may have adopted a too academic approach. He has been trying to determine a method of reducing sheath temperature to the accepted value. It seems that very early in the piece he had enough information to establish this, without taking it any further, not to establish it or to make sufficient advance towards it to assume reasonably that he might achieve his objective.

I am still left wondering, however, if he has actually solved the problem.

AUTHOR'S REPLY

W. G. JOHNSTONE (Christchurch M.E.D.)—In reply to Mr McCutcheon, I repeat that I have endeavoured in section 3 of the paper to set out, in simple sequence, a summary of the procedure which I have found useful in carrying out cable-heating calculations. The principle of superposition is also used by the E.R.A. Most engineers are familiar with and use the well-known E.R.A. report F/T 183, but have not time to become immersed in the details of reports dealing with cyclic loading, such as F/T 186 and F/T 192. It is shown in the paper that direct calculations involving cable groups can be made quite simply for conditions which are not covered by the mean grouping factor curves given in F/T 183. I do not consider that possible variations in soil conditions justify less accurate calculations, and dealt with this point in the paper (section 3.3).

Mr McCutcheon also questions the relative economics of the use of selected thermal backfill and artificial cooling. At the start of our investigations I had some doubt about the effectiveness of selected types of soil surrounding a cable in the general environment of sand, and it was decided to study in some detail the alternative possibility of water-cooling. The proposal to use a very stable backfill such as a cement-bound sand (i.e. weak-mix concrete) came later, at a stage when we had a better understanding of the thermal problem and were able to calculate the effect of its use with reasonable accuracy. Although water-cooling was shown to be practicable, and the installed cost of the piping itself relatively small (approximately 60c per cable per yard) the total cost was likely to vary considerably depending on the availability and cost of water, the existence of a suitable discharge point, or alternatively, the need to install heat exchangers. Reliable supervisory indication of water flow and water temperature would also be required.

On the other hand, it was found that a cement-bound-sand backfill could be installed for approximately $1.20 per cable per yard, with no continuing costs or maintenance difficulties; moreover this would have the advantage of providing some degree of mechanical protection against attack from mechanical excavators. On most of the route the natural sand had become contaminated with road-metal, and it would have been necessary to import suitable sand, or other material, to prevent damage to the cable surface if cement-bound sand had not been used, so that the net additional cost of the cement-bound sand would almost certainly be no more than $1 per cable per yard route.

The final decision was based mainly on practical considerations, after all the factors disclosed by the investigation had been taken into account.

Cooling water is usually fed in both directions along a cable route when a heat exchanger is used and the same water circulated continuously, and this would require at least two pipes per cable. It is not considered necessary to have water flowing in both directions when the water is discharged to waste. On a long route it may be desirable to have a water feed-point at each end, and the discharge point round about the mid-point of the route, in order to avoid excessive temperature rise of the cooling water; this could often have the practical advantage that the cooling would be more effective at the ends of the cable route where mutual heating from other cables converging on the substations concerned would make this desirable.

The object of the cooling is to keep the temperature of the soil surrounding the cable and pipe down to a value at which drying out will not occur, and there is then no risk of "thermal runaway".

With regard to thermocouples, referred to by both Mr McCutcheon and Mr Keys, we have in fact installed thermocouples along the 66 kV cable route, both on the cable sheath and at other points in the backfill, and the temperature rises obtained in practice will be compared with the calculated ones. Perhaps I should mention that one of the points at which thermocouples are being installed is where the two cables are laid in ducts, at a depth of about seven feet, for a length of about 90 ft. The temperature rise would normally be greater at this depth, and to overcome this, the spacing between cables is being doubled, the ducts have been set in concrete, and they are being filled with a special grout to avoid the derating effect normally obtained when ducts are used.

There should be no serious difficulty in laying 2 in polythene pipe for water cooling. The pipe would be secured to its associated cable at suitable intervals to hold it in position. It is supplied in coils of up to 200 yd in length, and standard jointing techniques would be used.

Mr Powell comments that we have planned a fair way ahead, and it is correct that the loads planned for are those expected towards the end of this century. Someone else can look after the problems that arise thereafter.

Laying cable in canals was not found to be a satisfactory method in Britain, although cables have been installed along paths beside canals. I must protest at the Avon being described as a canal, but nevertheless admit that all sorts of things can be seen in its bed, and that the occasional dredging which is required would be a complication if cables were laid in it.

With regard to the value of g, which I have taken as 120, it is generally agreed that this is a safe average value for soil conditions in both the United Kingdom and New Zealand although lower values are used in some countries. If sheath temperature rises are calculated as suggested in the paper, then they can easily be corrected for any known average value of g as they are directly proportional to it. I might add that a value of $g = 90$ is being used for the next 66 kV cable route now being planned, where the soil conditions are much more favourable.

In reply to Mr Keys' comments, I am pleased to note that this paper may have benefited some engineers by drawing attention to the fact that any clean sand is not necessarily a good bedding material. I was surprised to see that so little consideration had apparently been given in Auckland to the thermal properties of the materials round their supertension cables.

I think Mr Keys' confusion may have been cleared up by my replies to Mr McCutcheon regarding the methods adopted on the 66 kV cable route. I would point out, however, that in section 2.4 of the paper, it was explained that "after a careful study" involving the electrolytic tank model and consideration of other factors mentioned, it was decided to adopt the method of selected backfill. The rest of the paper was devoted to making available some of the information obtained as a result of the study, and Mr Spence's paper described some of the experimental investigations. I would suggest that this is a normal and correct way in which to set out papers giving such information.

Mr Keys suggests that the approach is too academic, but I think it is better to err in this direction than in another direction of doing insufficient investigations and calculations. In answer to his query, even if we have not solved the problem, at least we have done our best to do so.

Analogue for solution of cable-heating problems

R. D. SPENCE, B.E.
(Assistant engineer, Christchurch M.E.D.)

An electrolytic tank was used as an electrical analogue for the solution of steady and cyclic load cable-heating problems, which were difficult to solve mathematically. Also represented were models of water-filled cooling pipes which, in conjunction with suitable circuitry, enabled water and cable temperatures to be obtained at any position along the cable route.

1. INTRODUCTION

WITH the discovery that several of the Christchurch M.E.D.'s 11 kV underground cables in the Bromley district were reaching high temperatures for their load (in one extreme case a sheath temperature of 240°F was measured), the importance of soil conditions was realised, especially with 66 kV underground cables envisaged in the near future. The soil in this area is wind-blown sand of extremely uniform particle size, having very poor thermal properties.

Nearly all cable ratings are based on a soil thermal resistivity of 120 deg C cm/watt, but because this sand when dry had a much higher value of 250 to 350 deg C cm/watt, considerable investigation was necessary which required an analogue for solving the more complex cable heating problems.

Although the electrolytic tank was chosen, other types of analogue are:

(i) Two or three dimensional resistance networks, and

(ii) "Teledetos" electrically conducting paper using metallic paint for isotherms.

2. CABLE HEATING FORMULAE

2.1 Cables without cooling pipes

E.R.A. reports F/T 187 and F/T 192 give formulae for the external thermal resistance of isolated, or grouped cables having non-cyclic loading, from which can be calculated the sheath or conductor temperature rises. The absolute temperatures are found by adding the ambient ground surface temperature.

2.2 Cables with cooling pipes

Using the superposition method, the Christchurch M.E.D. has produced formulae for calculating the cable sheath and pipe water temperature rises in terms of position along the cable route.

The following formulae are for a single cable under constant load, cooled by an adjacent water pipe.

(i) *Water temperature known.*

If the water temperature ϕ deg C with respect to the ground surface is known at any position along the cable route, then the cable sheath temperature rise can be calculated at this point by equation (iii) of the appendix of the preceding paper.

Heat flow to the pipe W_p is given by equation (i) of the same appendix.

(ii) *Water temperature not known.*

If the water temperature along the cable route is not known, but the initial water temperature θ deg C with respect to the ground surface is, then the cable sheath and pipe water temperature rises can be calculated for any position distance L along the cable route by equations (vi) and ('x) of the same appendix, which give T_w and T_s.

The heat flow to the pipe at distance L is given by equation (ix).

(iii) *Two cables and pipes.*

This arrangement is easy to solve if it is symmetrical. An example is shown in Fig. 1 in which both cables dissipate W watts/cm.

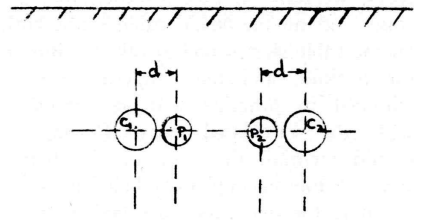

Fig. 1

Heat flow to either pipe is

$$W_p = \frac{W(G_{c1p1} + G_{c2p1}) - \theta}{G_i' + G_e' + G_{21}'} \exp \beta \quad \ldots\ (12)$$

where

$$\beta = -\frac{L}{4{\cdot}18Q\,(G_i' + G_e' + G_{21}')}$$

Cable sheath and pipe water temperature rises are:

$$T_w = W(G_{c1p1} + G_{c2p1})(1 - \exp\beta) + \theta \exp\beta \quad \ldots\ (13)$$

$$T_s = W(G_e + G_{21}) - (G_{p1c1} + G_{p2c1})W_p \quad \ldots\ (14)$$

(iv) *Many cables and pipes.*

This type of heat-flow problem is generally difficult to solve mathematically, and is more suited to analogue solution.

2.3 Symbols

All symbols used are standard E.R.A. notation, except for those listed in the preceding paper, which apply with cooling pipes.

3. APPROXIMATIONS IN FORMULA

All formulae given for the external thermal resistance of a cable are based on the assumption that the ground surface in contact with free air is an isothermal.

Equations giving the external thermal resistance contribution of one cable or pipe to another cable or pipe in a group apply for a point only. Cables and pipes are good heat-conducting bodies, and not points, and so form circular isotherms which cause distortion of the heat flow pattern. This error is dependent upon the proximity of the cables, or cables and pipes.

Likewise, equations giving the self external thermal resistance (G_e or G_e') of either a cable or pipe in close proximity with another cable or pipe would be in error to a small extent owing to the presence of a good heat-conducting body. This effect which is difficult to calculate, is present whether heat is being added or removed from that body.

In calculations it is assumed that G_{ep} is equal to G_{pe}, but it should be realised that this holds only if both pipe and cable are of approximately the same diameter.

It has been assumed that the cable sheath is an isothermal as also is the water in the pipes, because it is moving.

4. CYCLIC LOADING OF CABLES*

4.1 Cable groups

To calculate the temperature rise of a particular cable in a group, the E.R.A. reports show that the average watts lost, μW, (W = peak load watts, μ = loss load factor) over a 24-hour period for each of the group cables should be used

* E.R.A. reports F/T 186, F/T 192.

to calculate their mutual heating effect, provided all cables are sufficiently far away from the cable under consideration. This is due to the thermal capacity of the soil. To quote E.R.A. Report F/T 192—"In practice *sufficiently far* may be interpreted as 12 in or more for cables conforming to BS 480:1954, but for a large proportion of applied load curves this distance may be much reduced." The same report gives a method for cable groups in which the value μ cannot be assumed owing to the close proximity of cables.

For the cable under consideration, the loss load factor will not give high enough temperatures owing to the reduced effects of soil thermal capacity and the conductor cyclic loading factor F_c must be calculated, the conductor temperature rise then being calculated using a wattage of W/F_c^2 where W is the peak wattage. Hence, for an isolated cable, the conductor temperature rise is:

$T_c = W(G_e + G_i)/F_c^2$

By assuming the thermal capacity of the cable is negligible the sheath temperature rise can readily be calculated:

$T_s = W(G_e + G_i)/F_c^2 - WG_i$

$= F_s W G_e$

4.2 Cables and pipes

With a number of cable-pipe groups the mutual heating from each group will be determined by the average value of cable wattage and the average value of pipe wattage from each group.

For each pipe-cable group, the ground temperature at the pipe position will cycle slightly less than at the cable position and may reach its maximum temperature slightly later than the cable sheath. This maximum ground temperature would be lower than that calculated using a cable dissipation of $F_s W$ so that the maximum pipe wattage Wp would be lower. This means that the cooling pipes would be slightly less effective than calculated.

The closer the cable position under consideration is to the start of the cooling pipe system, and the faster the water velocity the more likely the water temperature at this point will cycle in phase with W_p. In practice the pipe water is unlikely to have been subjected to the same rate of heating from the cable, over the whole of the route so that at peak load time the water temperature will be lower than expected. This will drop the temperature of the cable sheath by a slightly larger amount than calculated.

As these two effects tend to oppose, they were both neglected.

5. APPLICATION OF ELECTROLYTIC TANK ANALOGUES

It is not difficult to calculate the temperature rise of any cable in a large group of cables, provided they are not too close. For cables in close proximity, temperature rise formulae are only approximate, and if cooling pipes are present, calculations become difficult.

With a large number of pipes and cables, it becomes difficult to calculate the pipe water and cable sheath temperatures along the cable route.

The electrolytic tank analogue is suited for solving thermal problems of this type, by using suitable scaling factors, and representing

Temperature (T) as Voltage (V);
Heat flow (W) as Current (I);
Thermal resistance (G) as Electrical resistance (R).

The form of this analogue was a shallow wooden tank, filled with water, and made to represent a vertical slice through the ground turned 90° into a horizontal plane in which quarter-scale brass or copper models of cable or cooling pipe isothermal surfaces were positioned. A brass plate was screwed to one inside edge of the tank to represent the isothermal ground surface.

6. APPARATUS USED WITH ELECTROLYTIC TANK

Wooden tank (4 ft 6 in×2 ft 6 in× 6 in)
Square wave audio oscillator
30 watt audio amplifier
Vacuum tube voltmeter for a.c. measurements
V.T.V.M. for d.c. measurements
Multimeter
Oscilloscope
1 s full-scale timer
2,000 μF 35 v.w. electrolytic condensers

7. ELECTROLYTE INVESTIGATION

Various electrolytes were considered, but because the interest was in using the tank as an electrical analogue, and not for field plotting, the electrolyte resistance had to remain constant and the boundary impedance very low, with both constant and varying current densities.

Earlier work by other investigators (P. A. Einstein (1951): Factors limiting the accuracy of electrolytic plotting tanks, *British Journal of Applied Physics, 2*), has shown that the equivalent circuit of the electrolytic tank could be envisaged as consisting of a resistance R corresponding to the main body of the electrolyte, in series with a parallel combination of resistance r and capacitance c, corresponding to the surface impedance of the electrodes.

It was also shown that, particularly at low frequencies, the magnitude of the reactance and degree of linearity were dependent on the current density and care in preparation of the electrode surface. The surface impedance falls with increasing frequency while the power factor angle varies only slightly at higher frequencies. This decrease is slow above 1,000 c/s to 2,000 c/s and the relative disadvantages of working circuits at high frequencies soon outweighs the resulting reduction of polarisation.

The Christchurch experiments were performed using 600-1,500 c/s square waves, the waveshape being selected because of its ability to eliminate greatly the effects of capacitive reactance. The potential difference between two electrodes in the electrolyte has a wave form of the type shown in Fig 2.

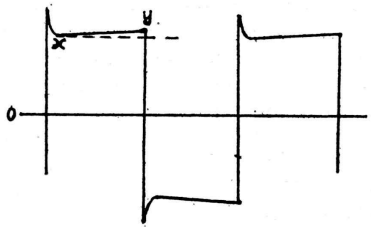

Fig. 2

The slope of plateau xy is due to increasing polarisation while the spike is caused by the reactive components.

Initial experiments were performed using 0.5 molar and 0.11 molar $CuSO_4$ solutions with polished concentric copper electrodes. Large variations of electrolyte impedance with time and current density quickly indicated the undesirability of this electrolyte.

The variation of electrolyte resistance with time, using water electrolyte and the same electrodes, was considerably improved at low electrode current densities (less than 0.005 A/in^2) indicating this combination to be satisfactory without any further precautions.

8. THE TANK AND CIRCUITRY

A wooden tank 4 ft 6 in × 2 ft 6 in × 6 in inside dimensions was made from 1 in coreboard and was firmly braced to prevent warping. All joints were interlocked and glued, and the tank given several coats of varnish.

The tank was carefully levelled, as any variation over its surface would introduce variations in electrolyte depth and so introduce errors.

Brass or copper tubes were used to represent to quarter scale the isothermal surfaces of cables, which normally is the outer armouring.

Figure 3 shows diagrammatically the layout and circuitry to measure the voltage rise of a constantly loaded cable together with the typical current or heat-flow pattern.

Note: (i) All the following calculations that are related to the electrolytic tank, use the standard thermal equations, except for V, R and I being substituted for T, G and W respectively.

(ii) The term "cable depth" refers to the distance from the tank edge and is not related to the water depth.

9. MEASUREMENT OF WATER RESISTIVITY

Experiments were performed using a water depth of 5 cm while the electrode currents were kept below 10 mA where possible. The water resistivity was measured using clean copper concentric cylinder electrodes. If R is the average resistance between the cylinders for different currents, then the water electrical resistivity is:

$$g_w = \frac{2\pi s R}{\log_e \frac{r_1}{r_2}}$$

where S is the water depth. It was not necessary to measure S as this cancelled out when temperature rises were calculated.

It quickly became apparent that g_w varied considerably with change of water temperature and this proved to be a problem. Values of R were of the order of 500Ω, giving g_w values of approximately 10,000 ohm cm which had to be measured two or three times a day.

An instrument check was made to determine if all instruments were correctly calibrated with 900 c/s square waves. The form factor of 1.11 was taken into account.

10. ELECTRODE POSITIONAL ERRORS

For a single cable model, values of self-voltage rise and mutual-voltage rise at points at the same depth were measured from 2% to 16% too high compared with calculated voltage rises. This seemed to indicate that the tank was too small, an effect which could be corrected by reducing the cable model distance from the tank edge.

11. EFFECT OF LIMITATION OF TANK SIZE

The shift in model position necessary to give the correct self-voltage rise for a single-cable model on the tank centreline can be calculated.

For a tank length S the current flow pattern is restricted by the tank boundaries. This pattern is identical to that for any one model in a tank of infinite size having an infinite number of models all at the same distance from the tank edge, same spacing S, and same dissipation. It was found that the tank width had only a small effect on the current flow pattern.

A single cable model in a tank of infinite size and at a distance l from the tank edge has a voltage rise

$$\frac{Ig_w}{2\pi} \log_e \frac{2l}{r}$$

For the same model dissipation this voltage rise is obtained with:

(a) an infinite number of cable models all at distance l_1 and spacing S, or

(b) one cable model centrally positioned in our tank at distance l_1

The voltage rise for an infinite number of cable models is:

$$\frac{Ig_w}{2\pi} \log_e \left[\frac{2l_1}{r} \frac{\exp \pi K - 1/\exp \pi K}{2\pi K} \right]$$

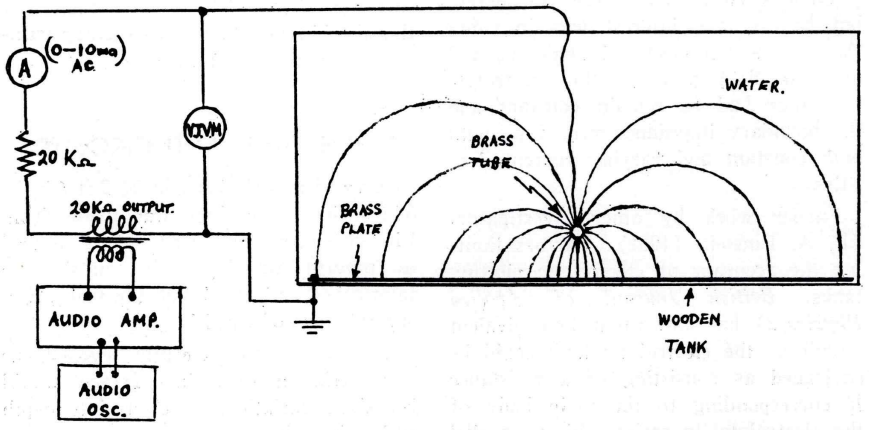

Fig. 3

where

$$K = \frac{2l_1}{S}$$

Equating these functions

$$l = l_1 \frac{\exp \pi K - 1/\exp \pi K}{2\pi K} \quad \ldots \quad (15)$$

This equation was used to check the experimental shift in model position necessary to give the correct self-voltage rise. Agreement within 1½% indicated that this shift was caused by the limitation of tank size.

The increase in tank size or decrease in model size necessary to reduce this model shift can be estimated, knowing the percentage of current that would flow outside the tank boundaries to reach the ground surface for the case of a tank having infinite dimensions.

The heat flow through the ground surface at position B or C (Fig. 4)

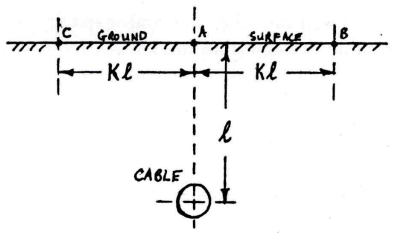

Fig. 4

where K is a variable and W is the cable dissipation per cm is

$$\frac{W}{\pi l (K^2 + 1)} \text{ watt/cm}^2$$

By integration the total heat flow through plane BC is

$$\frac{2W \tan^{-1} K}{\pi} \text{ watt/cm}$$

Applying this formula to the tank for a typical K value of 3.07, when using quarter-scale models, one found that a current equivalent to 20.3% of W would normally flow outside the tank boundaries.

A tank twice this size, with models to one-eighth scale would reduce this additional current to 5% of W.

12. ELECTRODE POSITION CURVE

Rather than increase the tank size, or decrease the model size, for convenience it was decided to shift the model position to compensate. The model positions were chosen to give voltage rises which corresponded to calculated values, using ¾ in diameter plain electrodes.

Generally only the centre cable of a cable group need be analysed because usually it is the hottest, so it seemed most important that the voltage rise of a cable at the centre of the tank be accurate. This meant the cable at the centre would be positioned for correct self-voltage rise and any other cables would be positioned on a curve giving correct mutual-voltage rise to the central cable.

By experimentation a curve as shown in Fig. 5 was derived which gave the modified position for correct mutual-voltage rise to the centre cable. The calculations were based on all cables having a scaled depth of 10½ in. This new curve representing an actual depth of 3 ft 6 in was pencilled on the tank bottom, and it was encouraging to observe that the self voltage rises of cables on this curve, as shown in Fig. 5, were in error by not more than 3.2% up to 2½ in from the tank ends.

Figure 5 shows the mutual-voltage-rise variation across the tank, for a cable dissipating current at (i) the tank centre, and (ii) at 6 in from the tank edge. The greatest error was 8% occurring over a small section of the tank, and was due to cables positioned near the tank edge. This method was chosen because it gave reasonably accurate results across most of the tank, with no error at the tank centre.

13. CABLE AND PIPE MODELS

The isothermal armouring (or metallic sheath) has a protective covering of higher thermal resistivity than the soil, and this should be represented in the tank. The logical answer was to reduce the water depth over a radial distance corresponding to the sheath thickness, but in such a way that the field pattern was not too distorted and the water depth not critical.

The method adopted was to cover with epoxy resin, brass rods that had been reduced in diameter on a lathe to correspond to the armouring outer diameter, then turn down their overall diameter to correspond with the outer cable diameter. Next grooves were cut through the sheath using a lathe set for thread cutting, and a square ended tool, such that

$$\frac{\text{Thread pitch}}{\text{Groove length}} = \frac{\text{Sheath thermal resistivity}}{\text{Soil thermal resistivity}}$$

Provided the water depth is sufficient and the groove pitch not too coarse, an even radial field pattern should result.

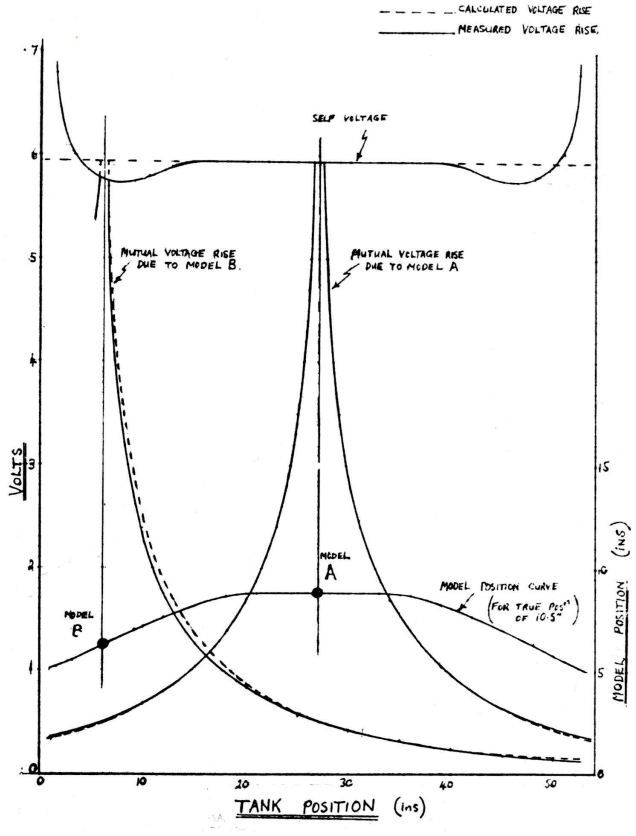

Fig. 5—Voltage rises using ¾ in D electrodes

The use of fine, uninsulated wires taped lengthwise on the models would probably have reduced the field distortion even more, but was not considered necessary.

Because experiments using cooling pipes were considered, models of pipes were made, with the pipe wall thermal resistance being represented in the same way.

Details of a quarter-scale model 66 kV cable are shown in Fig. 6. A different set of models having different thread pitch to groove length ratios are required for each soil resistivitiy chosen.

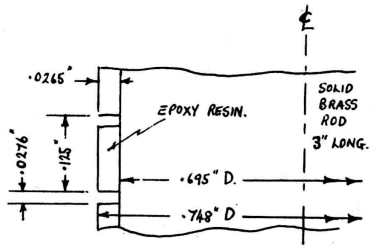

Fig. 6

In the experiments a thermal resistivity of 120 deg C cm/watt was chosen for the soil, while the value of the p.v.c. sheath was 542 deg C cm/watt. Using a thread pitch of 0.125 in, a groove length of 0.0276 in was required, which was checked by an optical microscope.

Details of a quarter scale model of a 2 in internal diameter polythene water pipe are shown in Fig. 7. Because polythene has a thermal resistivity of 400 deg C/watt, a thread pitch of 0.104 in in and groove length of 0.0312 in were selected.

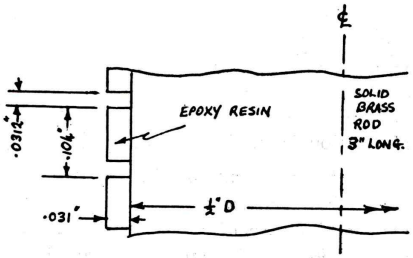

Fig. 7

A check was made on the distortion due to the cable grooves, by slipping a tight-fitting thin shim brass tube over the cable model, around which was concentrically positioned a larger brass tube.

Care was taken to ensure that no air bubbles were trapped in the grooves during this test. The resistance from model to outer tube was measured with and without the shim brass tube. Readings kept drifting, probably owing to polarisation caused by the greatly increased electrode-surface current density. This effect was reduced by using a square wave frequency of 1,500 c/s, and a model current under 5 mA.

Without the shim tube the resistance was higher, probably owing to distortion of the field lines caused by the cable grooves, while the presence of the shim tube would lower the water resistance owing to its thickness.

14. COMPARISON OF CALCULATED AND EXPERIMENTAL VOLTAGE RISES

(i) Using the curve for correct mutual voltage rise to a cable at the tank centre for a cable depth equivalent to 3 ft 6 in the differences between experimental and calculated results are shown in Fig. 8 for cable and pipe models at different spacing. The pipe model was not removing any current.

Owing to the insulating layer around both electrodes, the error caused by basing the calculations on line sources was small. The error in calculated cable voltage was only 2% when the models were touching, and decreased quickly with separation. Obviously the tank compensates for these calculation errors. With no insulating layers the pipe and cable voltages both change to the same value when they touch.

(ii) The superposition theory, and the mutual voltage change due to current subtraction or addition from a nearby pipe or cable respectively, were studied using plain $\frac{3}{4}$ in diameter electrodes. No discrepancies were observed.

(iii) A check between G_{cp} and G_{pc} for the cable and pipe models was made, while touching and at 1 in separation.

$$\frac{\text{Voltage rise of pipe owing to cable}}{\text{Voltage drop of cable owing to pipe}} = \frac{G_{cp}}{G_{pc}}$$

if the same current dissipation and absorption is used for both models.

Exact agreement within the limits of measuring accuracy was obtained, and also in the case of a 1 in diameter cable and a $\frac{5}{16}$ in diameter pipe at $\frac{11}{16}$ in separation.

(iv) *Pipe removing heat.* Using a modified model position curve for an actual cable depth of 3 ft 6 in a comparison was made between calculated and measured cable-model voltage rises with a pipe model alongside, removing current.

All voltage rises were within 1% of calculated values. This close agreement suggested that this method could be extended to a much larger number of cables and pipes having different water temperatures and cable dissipations, provided they were all at the same depth. These would be situations difficult to solve mathematically, but easy in the tank. Actual temperature rises are simply derived from the tank voltages by using suitable scaling factors.

15. TEMPERATURE CHANGE ALONG CABLE ROUTE WITH COOLING PIPE SYSTEM

Water and cable temperatures will rise with distance from the start of the cable route where the cold cooling water is introduced.

This effect can be achieved in the tank by analysing the voltages of pipe and cable, while storing the current flowing to the pipe in a condenser as shown in Fig. 9. By selecting a suitable capacitance value, an appropriate time interval can be achieved for a given cable route length.

The equation

$$\frac{t}{C_p\,(R_i' + R_e')} = \frac{L}{4{\cdot}18Q(G_i' + G_e')}$$

describes this analogy.

Where

$R_i' + R_e'$ is the internal plus external pipe resistance in the tank.

t is the time in seconds.

C_p is the storage capacitance of the pipe.

Both positive and negative pulses of the square wave were stored, but only half the total condenser voltage was measured as this allowed an earthed v.t.v.m. to be used, doubled the time interval "t", and simplified switching. Another reason why this rectification system was chosen in preference to a bridge was because the diode forward resistance, which was high, was halved.

Experiments were made to find diodes with low forward resistances, and the most satisfactory results were obtained using general purpose germanium transistors, with the base connected to the collector. The forward resistance of a single diode of this type is approximately 70 ohms at 2 mA and 19 ohms at 10 mA. Power transistors have a lower forward resistance, but also a lower back resistance.

Figure 9 shows a switch which can select three states:

(a) "Start" condition in which the pipe voltages are set to their initial value, and the pipes are absorbing their maximum current.

(b) "Run" condition during which the cable and water voltages will rise, and the timer will operate.

(c) "Hold" condition which can be selected after a given time interval, so stopping the timer and allowing the new pipe voltages to be measured. Unfortunately this advances the cable voltages to the state of no cooling pipes being present, but can give useful information for comparison. The cable voltages must be measured while rising, immediately

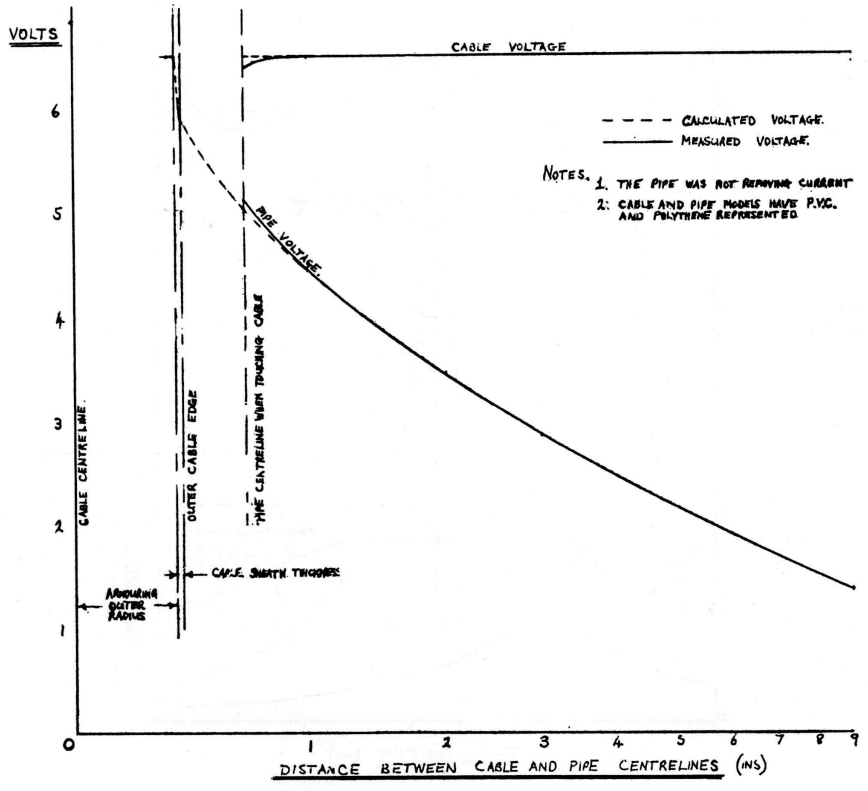

Fig. 8—Cable and pipe voltage rises with separation

prior to switching from the "run" to the "hold" positions. The "run" condition can again be selected provided no loss occurs in the electrolytic capacitors, so allowing more readings to be taken, equivalent to a further distance down the cable route. In order to reduce errors, it is better to return the system to the "start" condition and repeat for a new timing period.

The resistance of the tank water was such that even with a low water depth of 4 cm the capacity of the electrolytic capacitors needed to be at least 2,000 μF each, to give suitable time intervals. In the experiments for all pipes having the same thermal capacity, capacitors were padded to give capacitance values within 3%. This high capacitance was calculated by measuring their charge rate. Because of the instability of this type of capacitor, regular capacitance checks were necessary, and no high charging voltages used.

The tank resistance was low compared with the 20,000 ohm resistance in series, resulting in little change of cable dissipation current with condenser charging. This current could be corrected while in the "run" position if necessary.

Initial experiments were made with a single pipe and cable, then two pipes and cables, in order to check the validity of this method with calculations.

16. EXPERIMENTAL AND CALCULATED RESULTS

The following results were for cables and pipes laid at a depth of 3 ft 6 in, having a cable pipe spacing of $\frac{3}{8}$ in with all cables dissipating a continuous wattage of 0.13 watt/cm and all pipes having a water flow of 4 gal/min. A soil resistivity of 120 deg C cm/watt was chosen.

TABLE I

Condition	Pipe water: Calc. voltage V	Pipe water: Measured voltage V	Pipe water: Calc. temp. deg C	Cable sheath: Calc. voltage V	Cable sheath: Measured voltage V	Cable sheath: Calc. temp. deg C
$L = 0$	—	0.15	0.25	2.98	2.93	5.07
$L = 1{,}000$ yd	2.78	2.72	4.72	4.86	4.66	8.25
$L = 2{,}000$ yd	3.95	3.91	6.70	5.69	5.54	9.67
No pipe	—	—	—	6.34	6.44	10.80

The cable and pipe models had both p.v.c. and polythene represented and were placed in the tank at the appropriate modified positions.

Allowance was made in calculated voltage rises for the close proximity of cables and pipes using a factor derived from Fig. 8.

Owing to circuit limitations θ could not be lowered below 0.15 V, but this is relatively insignificant compared with most voltage rises.

The voltage to temperature rise conversion factor is:

$$k = \frac{Wg_{soil}}{Ig_w} = \frac{0{\cdot}13 \times 120}{0{\cdot}0036 \times 2{,}550} = 1{\cdot}70$$

(i) *One cable and pipe*

The following results in Table I were obtained corresponding to different positions along the cable route.

The greatest difference between calculated and measured voltages is less than 4½%.

(ii) *Two cables and pipes*

Because this is a symmetrical arrangement (see Fig. 10) calculations are not difficult and can be used to further check the validity of the electrolyte tank analogue.

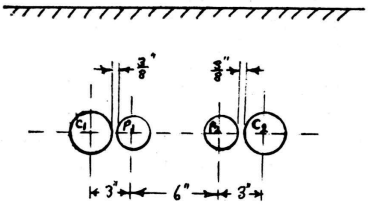

Fig. 10

The temperature rises in Table II were derived from the calculated voltage rises for soil having a thermal resistivity of 120 deg C cm/watt, the conversion factor being $k = 1.74$.

The greatest difference between calculated and measured voltages is less than 3%.

The timing interval is

$$t = 2\,\frac{L\,C_p(R_i' + R_e' + R_{12}')}{4{\cdot}18\,Q(G_i' + G_e' + G_{12}')}$$

$$= 2\,\frac{L\,C_p\,g_w}{4{\cdot}18\,Q\,g_{soil}}$$

as before

The cable sheath and pipe voltages are calculated by equations (13) and (14) after changing the symbols.

Because pipe and cable pair No. 1 were positioned at the tank centre, their voltage rises were the most accurate.

First one cable and pipe pair were considered as an extra check at the start of this experiment.

17. REPRESENTATION OF CYCLIC LOAD IN THE ELECTROLYTIC TANK

The approximate values of T_w and T_c for a particular cable were calculated by assuming the cable to dissipate $F_s W_1$ watts/cm and all other cables $\Sigma\mu_2 W_2$ if they are spaced sufficiently.

If in the tank, I represents W, then unfortunately these factors cannot be used because a cable model dissipating $F_s I$ amps would contribute too high a voltage rise to surrounding cable and pipe models, the correct value being μI. It is first necessary to make all cable

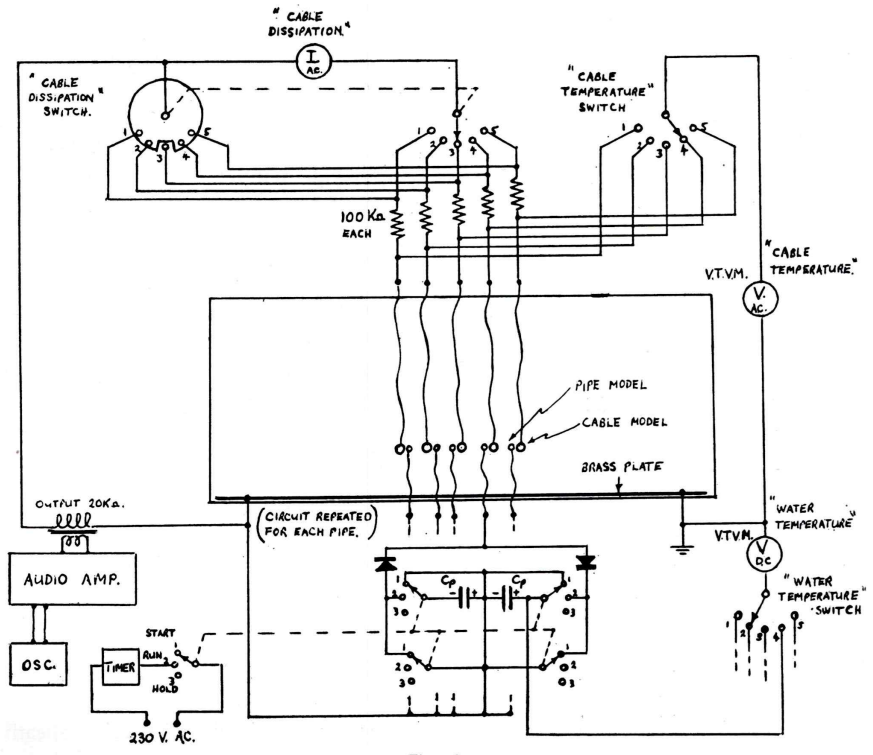

Fig. 9

models (with or without pipes), dissipate $\Sigma\mu_1 I_1$ amperes and measure the mutual voltage rise to the cable under consideration. Secondly, to this value must be summated the isolated effect of the same cable only, dissipating $(F_s-\mu)I$ amperes, its pipe if used, being still in circuit.

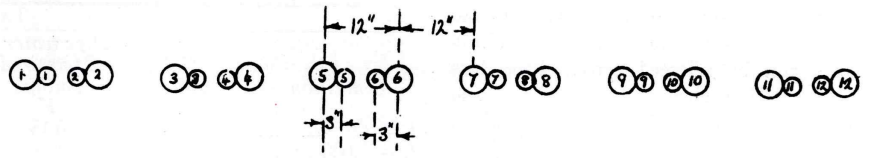

Fig. 11

17.1 Twelve cables and pipes

Because the previous results agreed reasonably well, this experiment studied the effect of a much larger number of cables and pipes; a case not easily calculated, but one which would occur at Bromley.

The cable-pipe arrangement was as in Fig. 11 with all cables and pipes laid at a depth of 3 ft 6 in and all cables dissipating the same wattage. All pipes had a water flow of 4 gal/min. The circuit shown in Fig. 9 was extended to 12 cables and pipes.

Cable and pipe models had p.v.c. and polythene represented and were placed in the tank at the appropriate modified positions. The voltages of pipe and cable pair No. 6 were measured, as this pair is the hottest, and being positioned centrally in the tank is the only pair whose voltage rises are reasonably accurate. Although the voltage rises of other cables and pipes are less accurate, their mutual heating effect to the centre is accurate.

Twenty-four 2,000μF, 35 v.w. electrolytic condensers were required and after carefully padding each, the capacity variation was 3,060 μF $\pm$ 1.6%.

Initially the voltage rises of cable and pipe pair No. 6 without the other models present, were calculated as a check.

(a) *Steady load condition* with all cables dissipating an equal steady load of W watt/cm. The results are summarised in Table III for cable and pipe pair No. 6. The conversion factor to derive the temperature rise for a model cable current of 0.0018A is:

$$k = Wg_{soil}/Ig_w$$
$$= (W \times 120)/(0.0018 \times 3{,}060)$$
$$= 21.8\,W$$

(b) *Cyclic load condition.* In practice loads are generally cyclic, so the sheath cyclic loading factor F_s must be applied (to the current dissipated by cable No. 6 and the loss load factor μ to the remainder of the cables. The loss load factor can be used because all pipe and cable pairs are spaced sufficiently from pair No. 6, which receives only an average heat contribution, owing to the soil thermal-storage capacity.

This experiment gave the maximum temperature rise of cable and pipe pair No. 6 for the case of all 12 cables having the same daily cyclic load, for which the loss load factor $\mu = 0.5$ and the sheath cyclic load factor $F_s = 0.7$. The results for this situation can be derived from the previous set of readings, assuming all cable models dissipate μI, to which must be added the separate effect of cable No. 6 dissipating $(F_s-\mu)I$ with its pipe present.

The conversion factor to derive the temperature rise is:

$$k = (W \times 120)/(0.0036 \times 3{,}060)$$
$$= 10.9\,W$$

It can be seen from Tables II and IV that for the same maximum cable load, temperatures are much lower with cyclic loading than constant loading.

(c) *Overload condition.* The situation envisaged was 10 cables dissipating a maximum cyclic load of 0.156 watts/cm, one middle cable and pipe (No. 7) out of service, and the other middle cable (No. 6) dissipating a maximum cyclic load of 0.833 watts/cm.

The voltage rises of cable and pipe pair No. 6 were measured which represent the maximum daily temperature assuming a loss load factor of 0.5 and sheath cyclic load factor of 0.7 for all cables.

The results showed the cable sheath and pipe water temperatures for the

TABLE II

	Condition	Pipe water: Calc. voltage V	Pipe water: Measured voltage V	Pipe water: Calc. temp. deg. C	Cable sheath: Calc. voltage V	Cable sheath: Measured voltage V	Cable sheath: Calc. temp. deg. C
One pipe and cable	$L=0$	—	0.15	0.26	2.92	2.84	5.07
	$L=1{,}000$ yd	2.69	2.63	4.68	4.74	4.64	8.23
	$L=2{,}000$ yd	3.84	3.78	6.68	5.55	5.43	9.65
	No pipe cooling	—	—	—	6.20	6.21	10.8
Two pipes and cables	$L=0$	—	0.15	0.26	3.04	$V_{s1}=3.02$ $V_{s2}=2.93$	5.29
	$L=1{,}000$ yd	3.29	$V_{w1}=3.23$ $V_{w2}=3.23$	5.71	5.43	$V_{s1}=5.45$ $V_{s2}=5.37$	9.45
	$L=2{,}000$ yd	5.16	$V_{w1}=5.12$ $V_{w2}=5.12$	8.98	6.84	$V_{s1}=6.79$ $V_{s2}=6.75$	11.9
	No pipe cooling	—	—	—	8.96	$V_{s1}=9.10$	15.6

TABLE III

Condition	Model	Measured voltage	Temperature (deg C) W=0.833	W=0.6	W=0.4	W=0.2	W=0.156
$L=0$	Cable	2.15	39	28	19	9.4	7.3
	Pipe	0.13	2.4	1.7	1.1	0.6	0.3
$L=1{,}000$ yd	Cable	4.65	84	61	41	20	16
	Pipe	2.80	51	37	25	12	9.5
$L=1{,}500$ yd	Cable	5.77	105	75	50	25	20
	Pipe	3.98	72	52	35	17	14
$L=2{,}000$ yd	Cable	6.62	121	87	58	29	23
	Pipe	5.00	91	65	44	22	17
$L=2{,}500$ yd	Cable	7.45	135	97	65	33	25
	Pipe	5.90	107	77	52	26	20
No pipe	Cable	11.9	216	156	104	52	40

TABLE IV

Condition	Model	Measured voltage	Temperature (deg C) W=0.833	W=0.6	W=0.4	W=0.2	W=0.156
$L=0$	Cable	2.15 + 0.75 = 2.90	26	19	12.6	6.3	4.9
	Pipe	0.13 + 0.06 = 0.19	1.7	1.2	0.8	0.4	0.3
$L=1{,}000$ yd	Cable	4.65 + 1.17 = 5.82	53	38	25	12.7	9.9
	Pipe	2.80 + 0.65 = 3.45	31	23	15	7.5	5.9
$L=1{,}500$ yd	Cable	5.77 + 1.28 = 7.05	84	46	31	15.4	12
	Pipe	3.98 + 0.82 = 4.80	44	31	21	10.5	8.2
$L=2{,}000$ yd	Cable	6.62 + 1.36 = 7.98	73	52	35	17.4	13.6
	Pipe	5.00 + 0.93 = 5.93	54	39	26	13.0	10.1
$L=2{,}500$ yd	Cable	7.45 + 1.41 = 8.86	81	58	39	19.3	15
	Pipe	5.90 + 1.01 = 6.91	63	45	30	14.7	11.8
No pipe	Cable	11.90+1.58=13.48	123	88	59	29	23

overloaded cable to be only slightly greater than for the case of a single cable and pipe subjected to the same overload condition.

18. CONCLUSIONS

Because square waves were used in this experiment, all r.m.s. readings were divided by 1.11, but this may be a little in error owing to slight waveform errors. However, the moving coil milliammeter and v.t.v.m., if in error, were so by the same factor, because used in conjunction with a standard resistance, they always indicated correct by Ohm's Law. If the square waves were not correctly shaped the integrated charge on the electrolytic capacitors would be in error, but because the moving-coil milliammeter reading is proportionate to the average current, this would probably compensate for most of the inaccuracy.

Frequencies from 600 - 1,500 c/s were used in the experiment and no serious effects due to variation of electrolyte electrical resistance or electrode boundary impedance were observed. At higher frequencies mutual coupling between circuits became annoying but below 600 c/s the low frequency response of the amplifier was not sufficiently good to provide well-shaped square waves.

Using cable and pipe models with p.v.c. and polythene represented, cable dissipations from 0.0005 A to 0.05 A were used, with only approximately a 3% variation in linearity of voltage rise, which may have been partly due to errors introduced by instrument scale changing.

The experimental errors increased as the complexity of the experiment increased, and were difficult to assess. The use of pipe models in conjunction with timed current integrating circuits increased the errors, which were further increased when the results of two experiments were summated, as in the case of cables subjected to a cyclic load.

By comparing the experimental and calculated results where possible, the discrepancy for most experiments was less than 5%. It must be remembered that the calculated results suffer from one source of error which is not present in the experimental results, and that is the mutual heating or cooling error for cables, or cables and pipes in close proximity.

It appeared to be advantageous to use low currents but unfortunately the lowest multimeter range (10 mA full scale) was not sufficiently accurate. It would be difficult to use a v.t.v.m. across a standard resistance because an earth is introduced. In contrast, if currents were too low, the diode forward resistance became appreciable.

It was unfortunate that cable depths could not be correctly represented in the electrolytic tank, but with a larger tank this should be possible owing to the reduced current field pattern distortion. This should result in correct mutual and self heating for all cables, rather than the centre one only.

Time did not allow investigation of cables and pipes at different depths, but with the present electrolytic tank they could be represented by positioning the models at modified positions to give the appropriate mutual heating to the cable under consideration.

If thermal dielectrics are to be represented as in the manner described, it is necessary to use a different groove width ratio for each soil thermal resistance selected. Adjustable tubes which slide over the models would solve this problem. To represent drying out around cables, or backfills, the water depth must be changed over the appropriate sections of the tank.

These experiments show that the electrolytic tank can be used to solve simple cable heat flow problems and also more complex cable heating and cooling systems.

Discussion

I. A. McCutcheon (Wellington M.E.D.)—Mr Spence investigates artificially-cooled buried-cable conductor temperatures with the aid of an electrolytic tank analogue and it is of interest to note the method he adopts to obviate the errors inherent with this particular technique. The U.K. Central Electricity Generating Board have conducted extensive investigations[1, 2] into the rating of artificially-cooled underground cables using an electrical-resistive analogue and it would appear that this method of attack is less prone to the errors inherent in the electrolytic-tank analogue.

One point Mr Spence appears to have overlooked is that of heating problems at the joint positions. Here cable conditions no longer apply since at joint positions there is a discontinuity in thermal conditions and also a very high thermal resistance between the conductors and outside of the cable box. It would appear that the limiting conditions for artificial cooling would be at the joint positions and I would like his comments on this. It seems that Mr Spence has lost sight of the most important consideration in his analysis and that is the correlation with acceptable rating.

An important point with respect to artificial cooling of buried cables would be to ensure that the thermal resistance between the cable and cooling pipe remains of constant value irrespective of moisture migration away from this material. This would entail the use of special bedding material around the cables and pipes to ensure adequate heat transfer. It would be reasonable to suppose that such bedding material would have a lower thermal resistivity than the surrounding sand or soil and this would add a discontinuity into the thermal flow analysis. It would therefore be impossible to represent this condition in the electrolytic tank model. Has Mr Spence any comments to make on this point?

I will reiterate what I said regarding Mr Johnstone's paper—that I consider the only really satisfactory solution to the problem of high temperatures in underground cables owing to unstable soil conditions, at these voltages anyway, is to use low resistivity bedding and backfill material and thermal supervision of the cable, at suspect locations. A case could, however, possibly be made out for using artificial cooling in conjunction with special low-thermal-resistivity bedding and backfill material so that ratings in excess of those normally acceptable could be obtained from the cable.

R. G. S. Powell (Waitaki E.P.B.)—Mr Spence's paper sets up analogues, tests the method of the fill and pipe and cable, which is subject to checking by calculation, for the single pipe and cable. He then goes on to extend that and to develop an analysis for a number of pipes and cables which is not so readily subject to mathematical analysis.

I presume it is a fair assumption that he gets the same order of accuracy. I wonder whether the results he obtained in this tank will provide parameters or constants or other checking figures which could be converted back to mathematical analyses for future reference. It would be useful if it could. This is really an extension of Mr McCutcheon's remarks about temperature tests. Is it envisaged that later tests will be made to verify the work that has been done so far?

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[1] Lis J. & Thelwell (1965) *Proc. I.E.E., 112,* No. 2 (February), p. 337.

[2] Hitchcock & Thelwell (1965) *Elect. Rev.,* 24 December.

M. G. KEYS (Auckland E.P.B.)—The analogue of Mr Spence is interesting and the discussion of his paper has removed one or two uncertainties in my mind, but some still exist. I felt it would have been better had he given more explicit details of one or two of these items, which raised doubts in my mind as to the real accuracy of the paper as a whole.

I am left wondering whether, having found the tank was too small to give accurate results, the answer might not have been to move the cable closer to the earth, or why Mr Spence did not go the full way and simply reduce the overall scale of the system, thus removing the need to make adjustments.

In spite of his comments on taking into account the sheathing g of the cable, I am still in doubt as to the justification of the method adopted—does this in fact give the results he claims. Another point I would like to have seen greater information on was where, by introducing capacitors, the temperature at a distance from the source of the pipe, the cooling water and the cable sheath, can be established. How is the rate of flow of water taken into account in this? The results show that for a rate of flow of water of 4 gal/min and g equal to 120 the cables can operate at the desired full load or cyclic loading, whichever they were designed for.

AUTHOR'S REPLY

R. D. SPENCE (Christchurch M.E.D.)—In reply to Mr McCutcheon, the resistance analogue has the disadvantage that it is difficult to make a resistance mesh which is sufficiently fine at the cable surface, especially if cooling pipes in close proximity are to be used. If different cable configurations are to be compared thermally, the electrolytic tank is by far the quicker method.

With the resistance analogue the cable internal thermal resistances can be represented, together with the sheath, dielectric and conductor losses, so giving the conductor temperature rise directly, but because all these are fixed known quantities, the conductor temperature is easily calculated knowing the cable sheath temperature. The main disadvantages with the electrolytic tank are that it requires precise model building, regular maintenance, and a large tank to model size ratio.

It is interesting to note that B. M. Weedy in his recent paper "Thermal aspects of changes in the environment of underground cables" used an electrolytic-tank analogue for his investigations.

Joints require more effective cooling, but at 66 kV the problem is not as serious as at higher voltages. Cooling is best achieved using plenty of good thermal backfill, possibly with increased cable spacing. If water pipes are used it may be necessary to use a water jacket or else several smaller diameter pipes to provide more effective cooling.

Owing to the logitudinal components of heat flow at a joint, it can be represented satisfactorily using a resistance analogue only by connecting several two-dimensional meshes in parallel to form a three-dimensional system. The cost of cooling the cable was far greater than cooling the joints, so it seemed more important that the Christchurch M.E.D. should conduct analogue investigations into cable heating, and provide joints with more than adequate cooling.

If a bedding material or backfill is to be used around a cable, it can be represented in the electrolytic tank by simply increasing the water depth over the appropriate sections.

In reply to Mr Powell, parameters such as the correction factor for the mutual-heating effect of cables in close proximity with other cables or pipes can be obtained from the electrolytic tank, and used in mathematical analyses. Generally every thermal problem has a changed set of variables and the only solution is to adjust the analogue and repeat.

It is hoped that with more investigation, a check can be made between field and experimental results.

In reply to Mr Keys, time did not permit us to experiment with a larger tank, but as all our problems involved cables at the same depth, it was sufficient to shift the model positions to compensate. Had cables been at different depths, a larger tank to model size ratio would have been necessary.

Many checks were made to determine the accuracy of cable serving and pipe wall representation by comparing voltage rises of pipe, cable and plain models, with calculation. In all cases close agreement was obtained, indicating the method to be satisfactory. The rate of water flow is allowed for by the symbol Q in the equation under Section 15. Just as the temperature of unit volume of water rises as it travels down the cooling pipe, so does the voltage of each pipe-model capacitor with time. The thermal storage capacity of the water can be likened to the current storage capacity of each condenser. This is accurate for steady loads or loads not too peaky. For peaky loads the pipe water may be cooler than expected because it is unlikely to have been subjected to the same rate of heating over the whole of the route, and so results will be on the safe side. For this type of load results are more accurate for shorter cable route lengths and faster water velocities.

Underground residential distribution using single-phase supply

N. R. WHITE, B.Sc., C.Eng., M.I.E.E., M.N.Z.I.E.
(Chief engineer, Tauranga E.P.B.)

In the changing pattern of modern living the need to satisfy the aesthetic demands of the community must be coupled with the public's ability to pay the price.

The method of underground residential development described in this paper and used extensively in North America is regarded by the author as a break-through in low cost underground reticulation.

1. INTRODUCTION

IN our rapidly changing environment more and more attention is being directed toward making our homes and their surroundings as attractive as possible. This means that those charged with establishing essential services for these dwellings bear an additional responsibility to see that their work is carried out with an eye to aesthetic appeal and that everything possible is done to see that the final result does not detract from the amenities of modern development.

Recent technical advances in cable manufacture, the development of new insulants, and improvements in cable laying and jointing techniques, have all contributed to a steadily reducing cost for underground distribution.

While passing through the United States and Canada in the course of a recent study tour the author of this paper found that single-phase supply seemed to have been adopted universally for underground residential distribution and that substantial economies were claimed to have resulted from the use of this system.

The principle of supplying remote rural consumers using a single-wire earth-return system originated in New Zealand many years ago and has been used continuously ever since. It was intriguing to find that, except for the addition of a metallic return path in the high-voltage feed, the system adopted as a standard for residential distribution in the United States and Canada is substantially the same as that which has been used for rural supply in this country for nearly 40 years.

Single-phase reticulation for residential distribution is not new in New Zealand as this was introduced some years ago by the Hawke's Bay E.P.B. and has been used by them and possibly others, ever since.

2. SCOPE OF PAPER

This paper describes the system which has spread rapidly in use in North America since its origin there some 20 years ago. Consideration is given to the application of a similar system for New Zealand conditions. Also included is a simplified economic appraisal of the various alternatives available in the manner in which a single-phase residential distribution system can be introduced.

The following alternative methods are examined:

(1) *High-voltage feed*: Comparison is made between the use of two neutral-screened cables connected between phases as an alternative to the use of a single neutral-wrapped concentric cable connected phase to neutral.

(2) *Cable-laying methods*: Two methods are compared:

(a) Trenching along both sides of the street with a single road crossing at the transformer position.

(b) Trenching along only one side of the street with a pipe duct at each alternate section boundary to serve over-road consumers.

(3) *Low-voltage feed*: The use of a 230/460 V three-wire secondary system has been compared with the use of a 230 V two-wire system.

(4) *Most economic size of group of consumers to be fed from a single transformer*: A survey of the cost per consumer taking into account all known

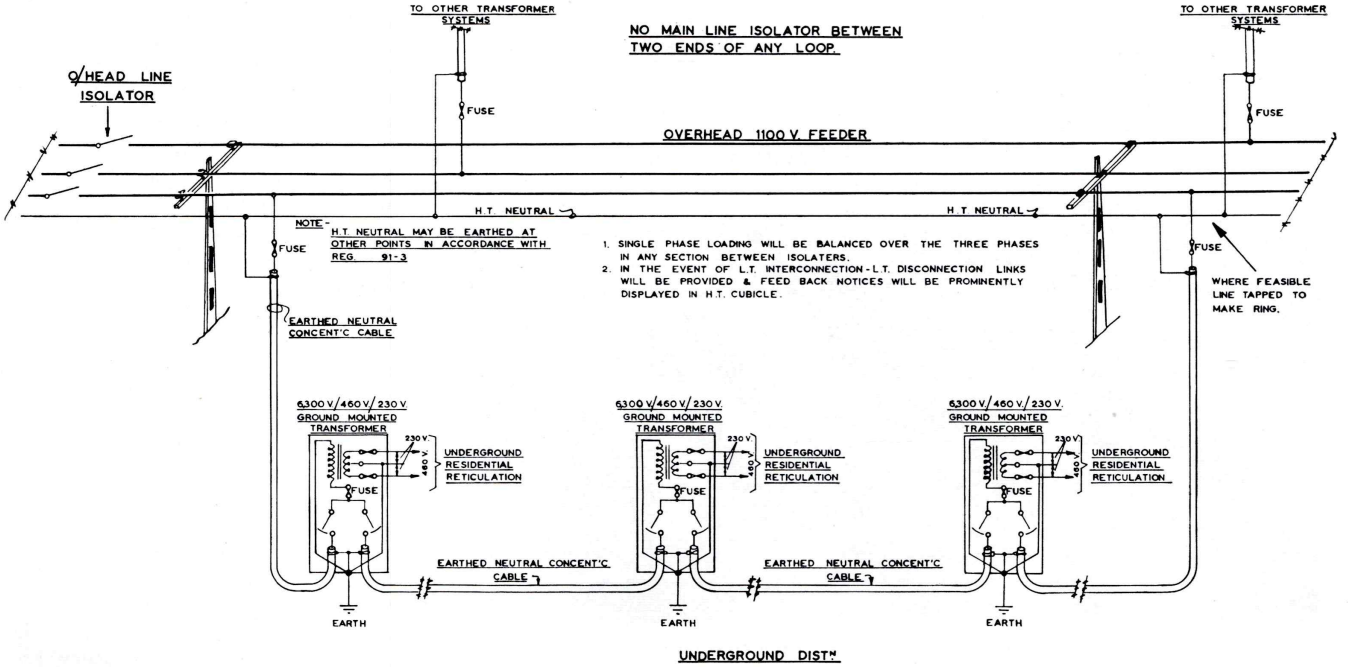

TO OTHER TRANSFORMER SYSTEMS
NO MAIN LINE ISOLATOR BETWEEN TWO ENDS OF ANY LOOP.
TO OTHER TRANSFORMER SYSTEMS
O/HEAD LINE ISOLATOR
FUSE
OVERHEAD 1100 V. FEEDER
FUSE
H.T. NEUTRAL
H.T. NEUTRAL
NOTE - H.T. NEUTRAL MAY BE EARTHED AT OTHER POINTS IN ACCORDANCE WITH REG. 91-3
FUSE
1. SINGLE PHASE LOADING WILL BE BALANCED OVER THE THREE PHASES IN ANY SECTION BETWEEN ISOLATERS.
2. IN THE EVENT OF L.T. INTERCONNECTION - L.T. DISCONNECTION LINKS WILL BE PROVIDED & FEED BACK NOTICES WILL BE PROMINENTLY DISPLAYED IN H.T. CUBICLE.
FUSE
WHERE FEASIBLE LINE TAPPED TO MAKE RING.
EARTHED NEUTRAL CONCENT'C CABLE
6300 V/460 V/230 V GROUND MOUNTED TRANSFORMER
230 V
460 V
UNDERGROUND RESIDENTIAL RETICULATION
FUSE
6300 V/460 V/230 V GROUND MOUNTED TRANSFORMER
230 V
460 V
UNDERGROUND RESIDENTIAL RETICULATION
FUSE
6300 V/460 V/230 V GROUND MOUNTED TRANSFORMER
230 V
460 V
UNDERGROUND RESIDENTIAL RETICULATION
FUSE
EARTHED NEUTRAL CONCENT'C CABLE
EARTHED NEUTRAL CONCENT'C CABLE
EARTH
EARTH
EARTH
UNDERGROUND DIST^N

Fig. 1—Typical connections of a single-phase ring main

factors for the range of loads which can be conveniently fed from a single transformer.

(5) *Single-phase v. three-phase*: A comparison with system proposed and the equivalent with a conventional three-phase supply system.

3. OVERSEAS PRACTICE

With few exceptions it seems to be almost universal practice in the United States and Canada for underground residential distribution (u.r.d.) to be carried out with a phase-to-neutral single-phase supply using a single neutral-wrapped concentric high-voltage cable for supply to distributionn transformers.

As far as is known there is no regulation in force in North America requiring a neutral to be covered when laid in the ground, and in every case encountered cable was laid with neutral wrapping bare and in direct contact with ground. So great is the value placed on the additional contact between neutral and ground that North American engineers expressed surprise to learn of a New Zealand regulation prohibiting this practice.

3.1 Phase-to-neutral system

With this system it is necessary to establish a fourth connection along the feeder route from the neutral point of the supplying substation, but where a lead-sheathed three-phase cable is used as part of the feeder system, the lead sheath of the cable is used for the fourth wire being extended as a fourth conductor when an overhead line carries on beyond the limit of the three-phase cable.

Figure 1 shows a typical connection of a series of single-phase transformers using the system mentioned.

When a single-phase spur line is run to a portion of a new subdivision from an existing overhead feeder, a connection is made from the appropriate phase through protection which can employ a liquid or conventional type of drop-out fuse. Where the connection is made from an underground feeder cable, a fuse box is available which is suitable for direct burial in ground.

3.2 Phase-to-phase system

Although only one case was encountered of a utility which preferred the phase-to-phase high-voltage feed system in preference to the phase-to-neutral system, there are points in favour of the former method if by its use the necessity to extend a fourth wire long distances from the substation can be avoided, and an economic comparison between both methods for each particular application is prudent.

In general the consensus of opinion in North America was that the phase-to-neutral system was less costly and the great advantage of having only a single-phase voltage inside the high-voltage compartment with consequential reduction possible in clearances and physical size, more simplified protection and isolation, and the requirement for only a single high-voltage bushing, more than justified the use of this system.

Whether all of these advantages will apply equally in New Zealand has yet to be determined.

In the main the cable which is most commonly used for high-voltage feeds is insulated with cross-linked polythene although butyl rubber and p.v.c.-insulated cables are also used to some extent.

Figure 2 shows the types of cable used.

3.3 Low-voltage arrangements

The low voltage most commonly used is 110/220 V. Connections to most homes are between the centre neutral point and one of the outers of the three-wire system although the 220 V across the outers can be used where there is a demand for a higher voltage.

3.4 Transformer types

In the early stages of a scheme most authorities use a pad-mounted (above ground) transformer which incorporates a two-compartment cubicle at one end. One compartment contains the high-voltage bushing, associated switching and fusing, and high-voltage cable terminations; the other (and smaller compartment) is used to house the low-voltage connections and the secondary circuit-breaker resetting handle. As the secondary is a three-wire secondary with centre neutral, only two bushings are required and the centre point of the secondary winding is earthed to a stud on the tank. By having both high-voltage and low-voltage compartments at one end of the transformer it is possible to use a single standardised type of concrete pad which can accommodate a wide range of transformer sizes.

As pad-mounted transformers, regardless of their size, have a standard lay-out for the high-voltage and low-voltage compartments, a change from one size to another is a relatively simple operation.

It is common practice to use transformers on a ring-feed system as shown in Fig. 1 with a feed available from two directions. Each cable as it enters a compartment is connected to an isolator which can be opened on-load with protective equipment available for the purpose. An oil-immersed or liquid fuse is used for high-voltage protection.

The secondary of the transformer is protected with a two-pole circuit-breaker which is set to the full-load rating of the transformer.

3.5 Totally- and semi-buried transformers

Although all authorities encountered agreed that a full-underground distribution system is achieved only when transformers are fully buried, many held the opinion that it was good practice to establish an underground system with the initial use of pad mounted (above ground) transformers:

Of the reasons advanced were:

(i) Lower cost of above-ground installation.

(ii) Greater access for isolation and change.

(iii) Ventilation of a buried vault is still capable of improvement.

It was generally contended that a pad-mounted transformer could be used with a low-profile enclosure and that its general appearance did not to any extent detract from the character of a housing development, and that the small aesthetic benefit of completely burying a transformer was out of all proportion to the additional cost of the installation as well as the lower transformer efficiency resulting from imperfect ventilation.

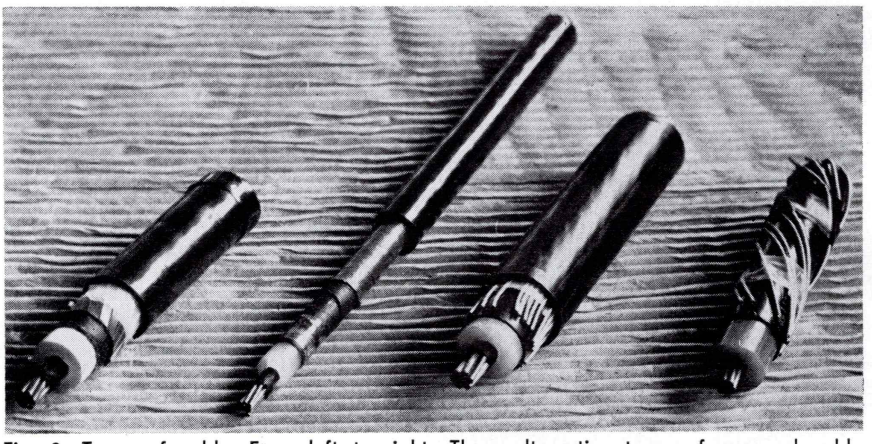


Fig. 2—Types of cable. From left to right—Three alternative types of screened cable (English 11 kV polythene, p.v.c.-insulated, type offered for use in New Zealand) and neutral-wrapped cable commonly used in U.S.A. & Canada.

Figure 3 shows photographs of a typical pad-mounted transformer of local manufacture.

3.6 Balance

All three phases on the main feeder are similarly loaded with single-phase systems so that in any switching section of a feeder a reasonable balance is effected.

Consideration must also be given to the maximum size of load in a single ring-feed capable of separate isolation in relation to the total load in the switching section so that in the event of its disconnection from the main feeder for any reason the resulting unbalance will not unduly disturb the feeder earth-leakage protection.

4. CONSUMER DEMAND

In planning an underground system the first and most difficult step is to determine as accurately as possible the after-diversity maximum demand (a.d.m.d.) that the underground system will have to accommodate during its economic life.

Because an underground system cannot be replaced or augmented as easily as an overhead system it is important to endeavour to get the answer right first time.

There is a strong incentive to be over generous in assessing future demand because this is the "safe" course, but if in the process considerably more copper (or aluminium) is buried than is actually needed it would have been better to have left it in the mine in the first place.

The opinion expressed in one technical paper presented in the United Kingdom was that the cabling system should be planned to cater for load growth for a period of 40 years. Establishing a system with a capacity adequate for a growth over such a long term does not necessarily provide the best economy.

The fact that cable manufacturing, cable laying and terminating costs are likely to fall with the passage of time together with the compounding annual charges on the unused capacity provided in the early years of a "long term" cable's life are factors which must be taken into account.

The determination of a figure for the a.d.m.d. of future residential load should be based on past experience, taking into consideration the trends in a.d.m.d. in the immediate past. It is doubtful whether there is any point in considering the trend for any more than the past 10 years as it was during this period that most of the high-consumption appliances have made their appearance.

Figure 4 shows the total demand of a group of consumers, plotted against the

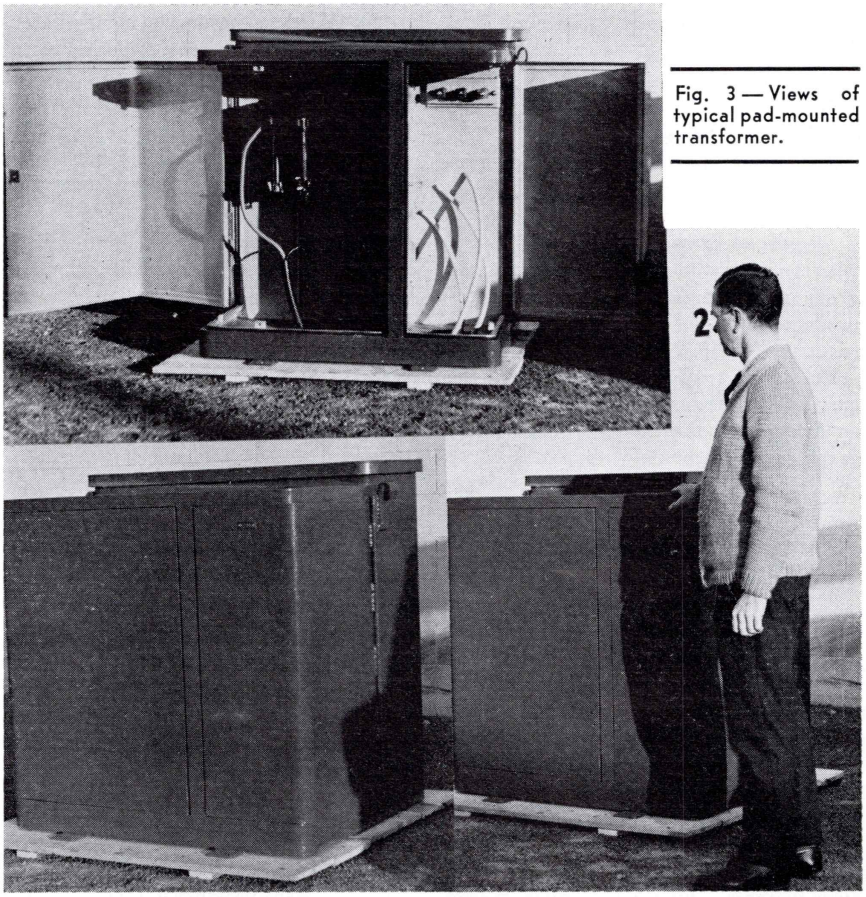


Fig. 3 — Views of typical pad-mounted transformer.

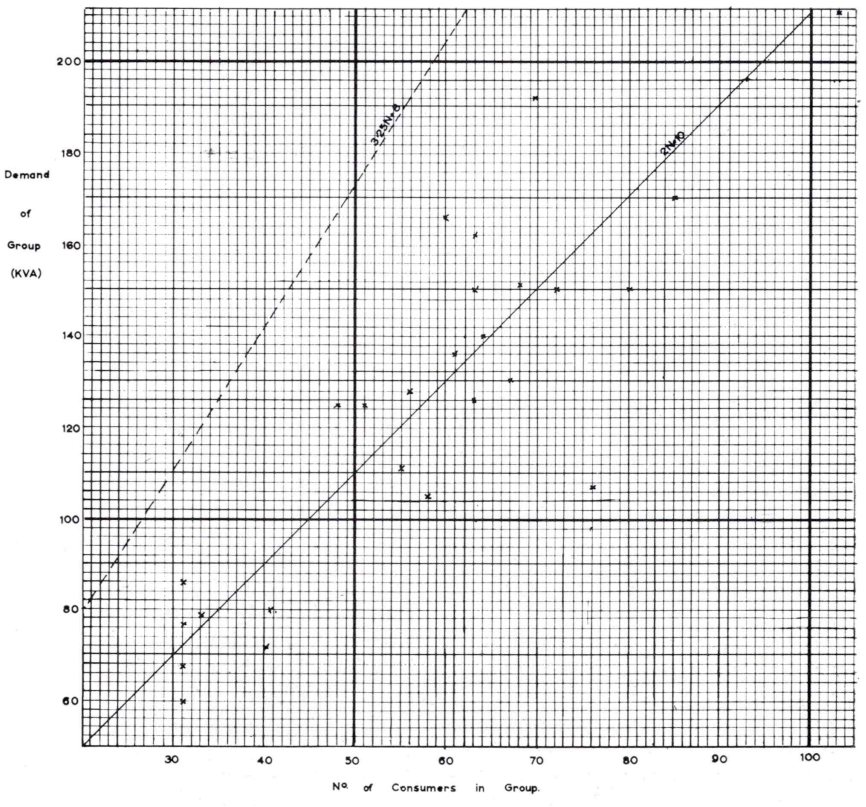


Fig. 4—Graph showing group demand of consumers

number of consumers in each group, as a result of actual tests taken in the last few months before this paper was prepared.

4.1 Effect of diversity

An attempt has been made to represent the present-day demand by a relationship in the form:

$$\text{Total demand} = An + B$$

where n is the number of consumers in group and A and B are factors appropriate to the load characteristics of the particular group.

Reference to Fig. 4 shows that the curve which seems most nearly to strike an average of the scatter points on the graph is represented by the curve

$$\text{Demand} = 2n + 10$$

This has been taken as a workable "present-day" curve for demand.

4.2 Future demand trends

The problem now arises as to what $An + B$ relationship should be taken to represent the demand at the stage when the system planned is approaching the end of its economic life. An examination of the a.d.m.d. trend of the "total" load of the Tauranga E.P.B. for the period of the preceding 10 years shows that the a.d.m.d. has increased by approximately 4% per year in this period. As the proportion of domestic to total load has also increased in recent years, it has been assumed that, to allow for this, the a.d.m.d. of residential load should be taken as increasing at a rate of some 5% per annum.

It was noted that the annual growth in a.d.m.d. for Tauranga was less than that for some other comparable authorities in New Zealand, and this has been attributed to the "congenial" climate that obtains in the Bay of Plenty.

In determining what adjustment, if any, should be made to past a.d.m.d. growth rates in assessing the future pattern, attention has been given to the following other pertinent factors:

(1) The possibility that the growth in space-heating demand may fall as a result of the increased use of other forms of energy, and the improvement in the efficiency of thermal insulation in modern homes.

(2) The fact that the full impact of the invention of the transistor has not yet been felt, and the effect this will have on the future improved efficiency of radio and television appliances.

(3) The continuing improvement in the efficiency of all forms of electrical household appliances.

(4) Whether the development of the fuel-cell as a source of domestic power has influenced, or is likely to reach a stage of development where it will influence demand in the foreseeable future.

(5) Whether the development of electric transportation, reported in recent months, will have any effect on consumer demand. It has been assumed that this form of load is very likely to be mainly "off peak" and not a significant factor in consumer demand in the foreseeable future.

(6) It is expected that there will be increased use of air conditioning but because this is summer loading it seems unlikely that this will have the effect of increasing residential a.d.m.d.

(7) Current Government policy in "dampening down" the consumer demand.

After considering all relevant factors there appears to be no evidence to suggest that in the foreseeable future the past a.d.m.d. growth rate will be exceeded, or even maintained, and a figure for demand based on the formula

$$\text{Demand} = 3.25n + 8$$

has been used in the planning of underground cabling systems for residential development.

It is intended to use the present-day relationship of

$$\text{Demand} = 2n + 10$$

for transformer provision as this can be easily corrected when required.

It has been recognised that the foregoing appreciation is influenced by widely varying factors and it is doubtful whether even the most precise and rigid treatment of the problem of future demand would have provided the correct answer for the situation which will obtain in 20 to 30 years' time.

5. HIGH-VOLTAGE FEED

When a cable is manufactured using polythene as an insulant every effort is made to avoid the formulation of voids during the extrusion process.

Various papers dealing with this subject have stated that electrical discharges will occur in cavities within the polythene or at its boundaries. Such a discharge can lead to the eventual breakdown of the insulant but it has been said that, unless the discharge magnitude exceeds a certain critical value of about two pico coulombs, the electrical life of the polythene insulation is not appreciably reduced by the existence of discharges. The critical value of discharge is achieved with a working stress of about 100 kV/cm.

This critical value for working stress will determine the thickness of insulant for a cable as well as the minimum size of centre conductor. The use of a larger centre conductor using aluminium does overcome this effect to some extent. It has been decided that any cables ordered will have a centre conductor of physical size no less than that of 0.0225 in² copper.

In examining the economics of using two neutral-screened cables on a phase-to-phase connection as against a single neutral-return cable with a phase-to-neutral connection, the relative costs of the two types of cables are taken into account, as well as the cost of the fourth conductor to the substation neutral point required where the phase-to-neutral system is used. No account has been taken of the larger load that can be delivered over two cables at 11 kV as against a single 6.3 kV cable for the reason that the minimum size of conductor will have been set by the electrical stressing of the insulant or the fault capacity rather than the load to be carried.

It has been calculated that in an area served by an 11 kV feeder to supply a load of about 3 MW and of a length of four miles, the cost of establishing the fourth conductor could amount to about $2,000. This would work out to a cost of about $2 per consumer ultimately served.

In order to compare the two classes of cables the following prices have been used:

(1) 0.0225 in² copper polythene-insulated wrapped-neutral-return of 39/.029 p.v.c.-sheathed overall, *80c per yd.*

(2) 0.0225 in² copper polythene-insulated copper-tape-screened p.v.c.-sheathed overall, *61c per yd.*

Both of these cables have equivalent insulation thickness designed for use on and 11 kV 50 c/s system and are manufactured in accordance with N.E.M.A. Standard W.C.7.

From the above comparison it will be seen that the saving on high-voltage cable cost alone with the use of single neutral-return cable amounts to 42c per yard. This saving should be increased because of easier handling in the laying of a single cable.

At the stage of preparation of this paper it has been impossible to obtain a figure which represents the saving in cost in the transformers, cable terminations and in jointing when only a single 6.3 kV cable is used.

There can be no doubt that the flexible type of ring main arrangement depicted in Fig. 1 is much more difficult and expensive to achieve when a phase-to-phase system is used.

It is evident that any authority contemplating the use of single-phase distribution in residental areas would have

to weigh the various factors mentioned in selecting the method most suitable for any particular application.

6. CABLE-LAYING METHODS

A comparison was made between the two ways in which low-voltage mains can be run along streets from transformer to consumers to be serviced. One of these is by establishing a main feed on both sides of the street and providing a single road crossing at the transformer by means of a duct for supply to the over-road main. Although this method involves only a single road crossing, twice as much trenching, mechanical protection and backfilling is involved as is the case when the alternative method of establishing a single main only on the transformer side of road with ducts crossing the road to service two consumers at each alternate section boundary.

Factors to be considered include:

(1) Advantage is taken of effect of consumer diversity where a single mains cable is used.

(2) The costs of trenching and establishing over-road ducts.

It was decided that because of the possibility of interference to cables from excavation by other authorities, it would be prudent to make all road crossings by means of a duct of galvanised water pipe, not only to provide mechanical protection for cables but also to facilitate the replacement of cables in areas of costly re-excavation.

The possibility that horizontal cross-road ducts could be used as additional earthing was also investigated, and tests on ducts already installed have shown that an earth resistance of approximately 25 ohms can be obtained from a 47 ft length of 1¼ in pipe in the soils so far encountered.

In view of the past success in laying service cable with a wheel tractor-mounted mole plough, it was decided to try this method for cross-road pipe ducts. This has proved completely satisfactory providing the work is carried out in reasonable weather conditions and is done in advance of the installation of other services. By this means it is possible to establish a 60 ft cross-road 1¼ in galvanised pipe duct for a total cost of $44 per crossing, including conductor and jointing.

Where it has been necessary to use trenching methods the current cost for trenching, mechanical protection and back-filling of 75c per yard has been used.

In order to make a comparison between the two methods of feed a "typical" case of a transformer supplying 28 homes has been used.

Figure 5 shows the two configurations under consideration.

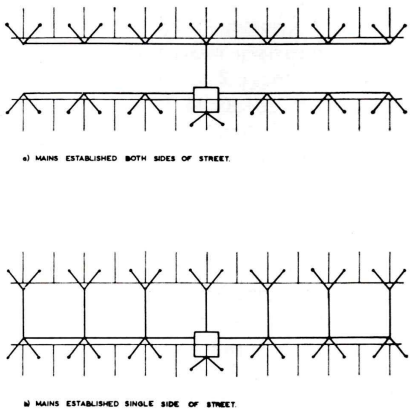


Fig. 5—Methods of establishing mains on one or both sides of street

In this examination the following assumptions are made:

Road width, 22 yd.

Section frontage, 20 yd.

Trenching, protection and backfilling, 75c/yd.

1¼ in galvanised pipe over-road ducts, including cable and jointing, $44 each.

Mains over-road duct including cable and jointing, $100.

Provision of cables, ducts and trenching

(a) Cables *both* sides

Duct including cables and joints	$100
Distributors 480 yd at 49.5c	$238
Pilots 480 yd at 16c	$ 77
Trenching, etc. 480 yd at 75c	$360
TOTAL	$775

(b) Cable on *single* side only

7 ducts at $44, including cable and jointing	$308
Distributors 240 yd at 63.9c	$154
Pilot wires 240 yd at 16c	$ 39
Trench, etc., 240 yd at 75c	$180
TOTAL	$681

Saving = $94

It will be seen that in the case examined a saving of more than 12% is obtained in trenching, cable and duct provision costs where single side of road supply is used. The saving results partly from the fact that because of consumer diversity a smaller single-cable size can be used than the combined capacity of cables on both sides of the road. In practice it has been established that generally there is more than 20 yd per section frontage, and this has the effect of making the savings for single-side reticulation even larger than estimated above.

After examining the factors involved in this comparison it was decided that single-side of road reticulation would provide the best economy. It was also realised that future conditions might require a change in location or an increase in the number of transformers serving a block of consumers and that this would be more easily effected where road crossings were provided independent of transformer positioning.

The calculations relating to the above estimates are tabulated in Appendix III.

7. TWO OR THREE-WIRE LOW VOLTAGE?

It was decided that a three-wire low-voltage system would be adopted for the following reasons:

(1) That after 20 years of experience of single-phase reticulation in North America the system which has evolved is a three-wire system.

(2) It is well established that more load can be carried over a given distributor if the voltage applied can be increased.

(3) As a 460/230 V system will result in smaller conductors than a 230 V two-wire system the cost of compression fittings and the labour content in making service connections will be lower for a three-wire system.

(4) That as loads increase the availability of 460 V between outer conductors could be of real advantage in the future.

Appendix I details the calculation in this comparison.

It was decided to design the low-voltage system with the objective of having under reasonably normal conditions, a maximum volt-drop of 10 V to the most distant consumer, but some allowance must be made for the increased voltage drop which will arise as a result of unbalance between the two outer "phases" of a three-wire system.

7.1 Effect of phase unbalance in a three-wire system

If the ideal case of a perfect balance could be attained between phases, no current would flow in the neutral and therefore all voltage drop would arise in the outer conductors. If, on the other hand, the extreme case of unbalance is obtained, e.g., a fuse blown in one phase and the other phase fully loaded, then all return current will flow in the neutral and the volt-drop on the most distant consumer (with supply) will be nearly doubled. It was decided that the effect of neutral voltage drop resulting from the type of unbalance that will eventuate in actual practice could be allowed for by taking a "compromise" permissible volt-drop which lies in the range between 10 V (condition of perfect balance) and 5 V, the figure that would have to be

adopted if allowance is to be made for an extreme case of unbalance, and entirely ignore volt-drop in neutral. It has been accepted that a blown fuse can be reasonably expected to be a fairly rare and short-lived occurrence, and the activity caused by a block of consumers who lose supply at a peak period would not allow the incident to go unnoticed for any length of time. For this reason it was considered that a "compromise" figure of 8 V maximum drop be acceptable. This means that under extreme unbalance conditions a total drop of 16 V could be experienced—6 V more than for a two-wire system designed for a 10 V drop. It was considered that as the system is designed to operate normally within statutory voltage limits a further 6 V drop for a limited period is unlikely to create any precedent.

In order to have some indication of relative costs, a case was studied of supply to 16 houses by both methods and based on the following assumptions: (Reference Appendix I)

(a) Loads follow relationship:
Demand $= 3.25n + 8$.

(b) Average section frontage 20 yd.

(c) Maximum volt-drop to further consumer: Three-wire case 8 V (neglecting any drop in neutral); two-wire case 10 V.

(d) Bias for load calculations given by a load of 11.25 kW at furthest consumer.

(e) The diversity advantage of the two-wire case allowed for in having two consumers of 11.25 kW (one in each leg) of the three-wire system.

(f) Conductor information from "AEI General Information Booklet".

(g) Recent aluminium prices were used.

(h) Computations were based on voltage drop as it was found earlier that this would be the factor determining conductor size.

The result of the comparison showed that the cost per yard was:

Cost of three conductors of 0.15 in² Al at a total cost of 93c per yd.

Cost of two conductors of 0.4 in² at a total cost of $1.26 per yd.

Apart from the further saving in cost of service connections, the use of three-wire shows a saving of about 8% over the corresponding cost of a two-wire system.

7.2 Most economic size of consumer group on a single transformer

Reference to Fig. 5b will show the method adopted for feed from transformer to consumers in a group. The four adjacent consumers to the transformer will be fed from the low-voltage compartment of the transformers and the balance of consumers will be fed by two three-wire distributors, one in each direction along the street.

The number of consumers fed from a single transformer can be represented by a relationship

$$\text{Consumer} = 8n' + 4$$

The comparison was confined to values of n' in the range 2 to 7 giving consumer groups of 20, 28, 36, 44, 52 and 60 houses.

Appendix II details the calculation for this comparison.

Assumptions are the same as those given in the two-wire *v.* three-wire comparison and only a three-wire distributor is considered.

No account has been taken for trenching, protection, backfilling ducts or service cable provision as these will not affect the comparison.

The four consumers fed directly have also been disregarded as they will not affect the comparison.

The result of this investigation shows that the best economy lies in the group of 36 houses served by a 125 kVA transformer. Allowance must be made for the fact that conductor sizes advance in definite steps with varying margins between calculated resistance and that obtained from standard conductors. This means that best economy could be anywhere in a slightly extended range.

An upper limit for transformer size is set not only by convenience in handling with regular supply authority lifting equipment but also by the type of subdivision to be served. In making the various economic comparisons it has been convenient to consider an "ideal" subdivision where it is possible to feed a certain number of houses from a centrally-situated transformer. Unfortunately no subdivision is ever planned with the objective of making distribution easy for the electric supply authority and there will be countless cases where the physical layout of a subdivision will dictate the group size. The comparison made was to show what gives the best economy if other factors do not intervene.

Another important aspect influencing transformer size is the value of feeder earth-leakage setting in relation to the maximum size of a transformer or group of transformers which can be taken out of service if connected as single-phase load.

7.3 Comparison of three-phase costs with single-phase equivalent

The foregoing survey has shown that the most economic configuration of a single-phase system uses single-side-of-road reticulation and a three-wire low-voltage system. So that the cost of this can be compared with the cost of an equivalent three-phase system a particular case of a 36-house consumer group has been used. Only factors which differ between systems have been compared. For example, as services and low-voltage connections to services would be essentially the same regardless of the system used, the costs of these have been omitted from the comparison. High-voltage costs have also been included. A precis of the calculation is included in Appendix IV. The result of this survey shows that a substantial saving results from the use of the single-phase system.

7.3.1 Low-voltage costs

With a 36-house consumer group the comparison between cost of low voltage by both methods is:

Three-phase 4-wire $269
Single-phase 3-wire $298

This makes the three-phase alternative the lower by about $30 or 10% of the total low-voltage cost, but this is very much more than offset by the savings realised when single-phase high-voltage is taken into account.

7.3.2 High-voltage cable

In examining the relative costs of supplying a proposed subdivision by three- or single-phase methods it is realistic to take total costs for the particular case of cabling between the point at which three-phase high-voltage supply is available and the transformers served.

With the three-phase case the cable must necessarily pass along the route of all transformers whereas in the single-phase case each individual cable may take the most direct route to the transformers to be served on that particular phase. This must result in a reduction in the total length where single phase is used.

This obvious and significant advantage has not been allowed for in the comparison following, where it has been calculated on the basis of only the length of high voltage which is encompassed along the route within the consumer group under examination.

On the assumption that 0.0225 in² Cu h.v. cable will be used it was found that for three-phase high-voltage supply it was slightly cheaper to use three-neutral-screened concentric cables (3 × 61c = $1.83/yd) than to use a three-phase lead-sheathed paper-insulated armoured cable ($1.92/yd). The comparison is:

	Three-phase 4-wire low-voltage	*Single-phase 3-wire low-voltage*
High-voltage cable (320 yd)	$585	$256
Distribution cost	$269	$298
	$854	$554

A saving of $300 when single-phase is used—amounting to a saving of more than $8 per house.

7.3.3. Transformer costs

At the time of preparation of this paper no price is available for single-phase transformers of the type required but it is expected that a further significant saving will be realised when single-phase transformers are used for the following reasons:

(1) Simplified core arrangement allows size reduction.

(2) The number of h.v. bushings, fuses, isolators and cable terminations reduced to one-third.

(3) Two-voltage bushings and connections reduced to two.

(4) Reduced clearances in h.v. compartment when only a single-phase h.v. potential is present.

It is expected that prices will be available in time for the paper's presentation.

7.3.4 Disadvantages of single-phase

Single-phase supply does have some disadvantages when compared with the three-phase alternative.

(1) Three-phase low-voltage supply cannot be provided to large motors.

(2) When single-phase supply is used there is a limit to the amount of transformer capacity that can be taken out of service before the resulting unbalance of load tends to affect the earth-leakage protection.

(3) Inevitably in a residential subdivision there is the possibility that small shopping areas will develop, and that this will require a three-phase supply for butcher shops, fish shops and garages. There would appear to be no reason why a single-phase and a three-phase supply cannot be integrated providing that no commitment has been entered into with residential consumers for a continuing supply at 460 V as this may at a later date be changed to 400 V supply.

There seems to be no reason why a three-wire system operating on two of the three available phases should not continue to be fed in three separate directions from a three-phase transformer.

8. PRACTICAL RESULTS

It was hoped that at the time this paper was prepared a single-phase reticulation system would have been completed in Tauranga, and an account given of actual experience. Delivery of single-phase neutral-return cable, stress cones and a prototype phase-to-neutral transformer has been expected for some time, but unfortunately at the time of preparation of this paper none of this material had arrived. Thus instead of an account of "how the project was done" this paper has of necessity had to become "what it is intended to do". It is hoped that by the time the paper is presented the materials on order will have arrived and that some account can be given of actual experience.

9. DEGREE OF ACCURACY

In the foregoing calculations many assumptions have been made and not the least of these has been the assessment of the trend of growth for future a.d.m.d. There seems little point in carrying out a detailed and rigid examination of various aspects of single-phase development when so little can be known of future consumer-growth trends. The appreciation of the problem presented in this paper has been one based on keeping the amount of detailed examination of various aspects of the problem to a realistic level.

10. RELATIONSHIPS WITH POST OFFICE SERVICES

The Engineer-in-Chief of the Post Office has now laid down conditions under which 6.3 kV neutral-screened cable may be used in relationship to Post Office cables. He has stated that there is no objection to the use of this type of cable provided that a minimum separation of 1 ft 6 in for parallel runs and unprotected crossings is maintained. For protected crossings, that is with 2 in of concrete between the cables, this separation may be reduced to 6 in.

The Post Office, which has shown considerable interest in this method of reticulation, has been supplied with details of overseas practices in the use of "random separation".

In North America the requirements for separation between telephone and power circuits vary from utility to utility but many authorities have arrived at an agreement with their fellow telephone authority to lay cables at what is known as "random separation". This means the installation of both power and telephone cables at the same depth in a single joint-trench with no deliberate separation between them. A joint I.E.E.E.-Bell System sub-committee was set up in 1956 to study the joint use of facilities by telephone and power companies in residential underground systems. The committee conducted a series of tests on power and telephone cables at the Line Materials short-circuit laboratory near Franksville, Wisconsin, U.S.A. Fault-current tests were carried out up to a figure of 6,000 A (at phase-to-neutral voltages of 7.2 kV and 7.62 kV) chosen as a likely maximum fault current on short distribution circuits under future fault level conditions.

Further tests are being conducted, and because the practice was not at the time able to be exercised in conformance with the National Electrical Safety Code, a Code of Recommended Practice was drawn up for further trial installations.

The use of a common trench in parts of North America for power and telephone cables at random separation has significantly reduced the overall cost of residental underground installations.

No doubt a great deal more will be heard of this trend in the future.

Appreciation

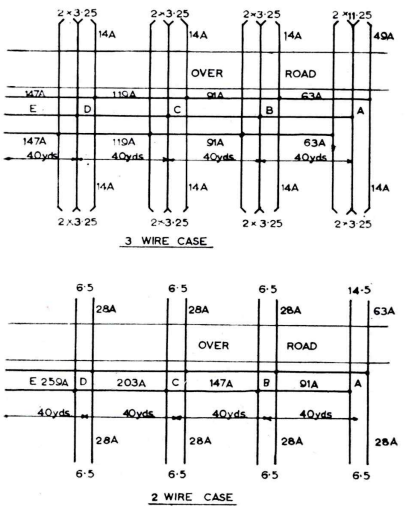
The author records his appreciation to the Tauranga E.P.B. for permission to present this paper and to use material prepared by the Board in a survey of future underground development.

He would also like to record his appreciation of the valuable contribution made by E. J. Hussey and K. D. E. Kelman, who not only carried out parts of the survey mentioned but also helped materially with the proof-reading and preparation of diagrams.

Tribute is paid to Lloyd Mandeno as the pioneer in single-phase reticulation. He devised and used a single-phase system in 1924, some twenty-five years before North American, Canadian and other utility authorities adopted an essentially similar system to his as a standard for underground residential development.

APPENDIX I

Comparison between two-wire and three-wire distributors to 16 houses



(*Continued overleaf*)

APPENDIX I

Comparison between two-wire and three-wire distribution to 16 houses

	Three-wire-case	*Two-wire case*
Volt-drop allowable	8 V	10 V
Volt-drop in 0.04 Al road crossing and 10 yd service	2.08 V	3.80 V
Volt-drop available along road	5.92 V	6.2 V
Distance volt-drop effective	40 yd (as neutral drop already allowed for)	80 yd (go and return)
Ampere-yards section A-B	2,520 Ayd	7,290 Ayd
Ampere-yards section B-C	3,640 Ayd	11,780 Ayd
Ampere-yards section C-D	4,760 Ayd	16,250 Ayd
Ampere-yards section D-E	5,880 Ayd	20,700 Ayd
TOTAL ampere-yards	16,800 Ayd	56,020 Ayd
Resistance per 1,000 yd given by: (v.d./Ayd) × 1,000	(5.92/16,800) × 1,000 = 0.353 ohms/1,000 yd	(6.2/56,020) × 1,000 = 0.111 ohms/1,000 yd
Nearest large conductor	0.15 Al (0.2711 ohms)	0.4 Al
Cost of this size conductor per yard	31c per yard	63c per yard
Cost per yard	93c per yard (for three conductors)	$1.26 per yard (for two conductors)
Cost of mains cable		
160 yd at 93c	$149	160 yd at $1.26 $201
Road crossings		
four at $51.00	$204	Four at $48.66 $198
Services (30 ft free)		
16 at $12.06	$193	116 at $12.06 $193
Total for distributor	$546	Total for distributor $592

Cost saved $46 (or saving of about 8%).

APPENDIX III

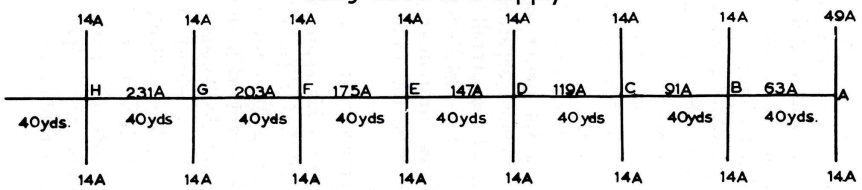
Assumptions: Refer to text

Layout: Refer Fig. 5.

		Both sides of street	*Single side of street*
Volt-drop permissible	V	8	8
Volt-drop 10 yd service	V	0.99	0.99
Conductor for road crossing		0.15 in² Al	0.04 in² Al
Volt-drop—road crossing	V	1.01	1.09
Permissible volt-drop in street mains (v.d.)	V	6	5.92
Ampere-yards			
Section A - B		1,960	2,520
Section B - C		2,520	3,640
Section C - D		3.080	4,320
Total ampere-yards	A yd	7,560	10,480
Resistance/1,000 yd of street mains (v.d./Ayd) × 1,000	ohms	0.794	0.564
Conductor selected		0.06 in² Al	0.1 in² Al
(resistance)	ohms/1,000 yd	(0.677)	(0.397)
Cost of conductor yard	c	16.5	21.3
Cost for three conductors	c	49.5	63.9
Length of cable trench (both sides of transformer)	yd	480	240
Total cost of l.v. distributors	$	238	154

APPENDIX II

Calculation to determine most economic size of transformer group using three-wire supply



Section	*Ampere-yards*
A - B	2,520
B - C	3,640
C - D	4,760
D - E	5,880
E - F	7,000
F - G	8,120
G - H	9,250

Transformer group		*20 houses*	*28 houses*	*36 houses*	*44 houses*	*52 houses*	*60 houses*
Initial transformer size	kVA	75	100	125	150	175	200
Houses on one distributor		8	12	116	20	24	28
Total ampere-yards	Ayd	6,160	10,920	16,800	23,800	31,920	41,170
Resist. of cable/1,000 yd	ohm	0.9615	0.542	0.3525	0.2489	0.1855	0.1438
5.92 Ayd × 1,000 ohm/11,000 yd							
Nearest large conductor		0.06	0.1	0.15	19/105 Al	19/128 Al	0.3
Resistance of cable selected	ohm	0.667	0.397	0.271	0.2458	0.1665	0.1324
Unit cost of conductor	c/yd	16	21	31	31	41	50
Cost of six conductors (two distributors)	$/yd	0.96	1.26	1.86	1.86	2.46	3.00
Total yards	yd	80	120	160	200	240	280
Total mains cost	$	77	152	298	372	590	840
Transformer cost	$	810	962	1042	1104	1196	1288
TOTAL COST	$	887	1114	1340	1476	1786	2128
Consumers on distributor		16	24	32	40	48	56
Cost per consumer served	$	55.40	46.40	35.30	36.70	37.20	37.90

APPENDIX IV

Calculation of cost of a three-phase system to supply a 36-house development

The same general assumptions are used as in earlier conductor-size calculations.

The transformers will feed two distributors each supplying 16 houses. Diversity has been allowed for by supplying the two most distant over-road houses at 11.25 kW each on (say) phases B and C. One house on the near side of the road at 11.25 kW is placed on phase A and the rest of the houses are, as far as possible, balanced between the phases. The effect of neutral volt-drop resulting from imperfect balance has been allowed for (as before) by reducing the allowable low-voltage drop from 10 V to 8 V and ignoring any drop in the neutral.

Details of the calculation will be available when the paper is presented so that only a precis of the steps in this calculation are given here.

(*Concluded opposite*)

		Phase A	*Phase B*	*Phase C*
Drops in service and over-road crossings to three furthest houses	V	0.99 (no crossing)	2.71	2.71
Volt-drop available for distributor	V	7.01	5.29	5.29
Total ampere-yards	Ayd	14,040	12,920	12,360
Calculated conductor resistance	ohm/1,000 yd	0.499	0.410	0.429

In selecting the appropriate conductor it would probably have been reasonable to average the three resistance figures but to provide a greater margin the conductor size for each phase and neutral was determined by the resistance calculated for phase B (0.410 ohms/1,000 yd).

Conductor choice 0.1 Al (0.397 ohms/1,000 yd).

Cost per yard of conductor 21c.

Cst per yard of eight conductors $1.68 (two distributors).

Cost for 160 yd of eight conductors $268.80.

Hight-voltage cable

In examining the relative costs of supplying a proposed subdivision by three-phase or single-phase methods it is realistic if the total costs are taken for the particular case of cabling from the point at which three-phase high-voltage supply is available to all of the transformers served.

With the three-phase case the cable must necessarily pass along the route of all transformers whereas in the single-phase case each individual cable may take the most direct route to the transformers to be served on that particular phase. This must result in a reduction in the total length where single-phase is used.

This obvious advantage has not been allowed for in the comparison following, where it has been calculated on the basis of only the length of high-voltage which is encompassed within the consumer group under examination.

On the assumption that 0.0225 Cu h.v. cable will be used, it was found that for three-phase h.v. supply it was slightly cheaper to use three neutral-screened concentric cable (3 × 61c = $1.83 per yard), than to use a three-phase lead-sheathed paper-insulated armoured cable ($1.92 per yard).

Throughout this survey it has been taken that a single-phase transformer will cost the same as the equivalent three-phase transformer. Overseas practice has shown a saving for the single-phase transformer resulting from the reduced size, reduced number of bushings and smaller oil content, resulting from the simplified core arrangement. Even allowing for the increased cost of providing high-voltage and low-voltage compartmen and h.v. switching and fuses, the saving should more than offset any increase in costs for single-phase transformers. Only actual experience will show whether or not this contention is correct.

The comparison is:

	Three-phase 4-wire low-voltage	*Single-phase 3-wire low-voltage*
	$	$
High-voltage cable (320 yd)	585	256
Transformer cost	1,042	1,042
Distributor cost	269	298
	$1,896	$1,596

Single-phase shows a saving of $300 or about 15% less than three-phase.

The most important point emerging from this comparison is that the low-voltage for single-phase distributor costs more than the equivalent three-phase, but as pointed out earlier, the additional cost is more than offset with use of single-phase high-voltage cable.

Discussion

D. J. Binns (Ashburton E.P.G.B.)—It is perhaps 10 years since plastic-insulated power cables came into general use in New Zealand and this marked a real "break through" in the cost of u.r.d. Then came the Institute symposium in 1961 and other papers associated with pad-mount equipment have followed.

Opinions differ slightly on relative costs and reliability of the various alternatives and by now each engineer has his own pet system, but to my knowledge no one in New Zealand has an answer to the complete undergrounding of residential distribution using plastic cables.

Because of the space required for high- and low-voltage protective equipment, if for no other reason, the single-phase method used to supply many thousands of homes in North America as described by Mr White has certain advantages and might be a further step along this road and Mr White has given a sound argument for a system of u.r.d. well tried elsewhere. However, it could have some disadvantages in regard to safety, particularly where earthing conditions are difficult.

The main disadvantages of the system are the ones listed in section 7.3.4 together with the obvious one of having to run a fourth h.v. wire. There are a number of urban areas where the l.v. earthed-neutral system is interconnected and is available for connection at the neutral of the bulk-supply transformers.

Has the use of a common h.v. and l.v. neutral been considered by Mr White? The return path thus obtained might be preferable to a single overhead h.v. wire.

In section 7.3.4, he mentions the integration of single- and three-phase supplies. Perhaps he would elaborate on how this is handled in the United States.

In section 6 the establishing of mains on one or two sides of a street are compared. I wonder just how he lays his galvanised pipe duct with a mole plough; how he does this with two kerbs to go under; how the roading authorities view a crossing every 40 yd in what might be a consolidated base ready for sealing; how he does this for $44 (although in Appendix I this appears as $51)?

In Fig. 5a has the author considered the economics of the both-sides configuration with additional across-street connections at the ends? A smaller-sized distributor might be chosen with this method.

In view of the fact that the Post Office has now agreed to random lay for certain cables, has Mr White considered a further approach to N.Z. Electricity Department in connection with the use of bare l.v. and h.v. underground neutrals?

What is the capacity of the pad-mount transformer in Fig. 3? Is it 125 kVA?

Does Mr White intend placing more equipment underground, e.g. transformers and service fuses, or is he content with another compromise solution?

I. A. McCutcheon (Wellington M.E.D.)—This is an interesting account of the use of single-phase underground distribution as it is applied in North America and it is important to bear in mind the reasons that resulted in the development of such a system.

First, with a secondary voltage of 110/220 V, there are very real problems of voltage drop and this has forced the Americans to the use of a large number of small transformers, rather than fewer transformers of larger capacity, as is standard practice in British countries.

Secondly, the availability of solid-insulant-type cables at bargain prices has played an important part. Neither the voltage problems, nor the cheap cable exist in New Zealand, and one wonders whether the Americans would have developed this type of system had they had the advantage of a 400/230 V secondary, and been obliged to pay solid-

insulant-type cable prices comparable with their paper-lead equivalents.

It is not apparent from the paper, but it should be known to all that underground residential distribution systems in North America are invariably in areas which can only be described as "urban sprawl". The houses are large and expensive and are single-resident dwellings. Has Mr White considered how to adapt this system to provide for large blocks of flats which are becoming so prevalent here? This could be done by the installation of a transformer, or transformers, in a particular building, but is Mr White of the opinion that single-phase transformers would still be the correct solution?

Another point brought out in the paper is that normally the u.r.d. areas are fed from an overhead line which skirts the perimeter of the subdivision. This is satisfactory as long as the overhead line is acceptable. No doubt pressure will come in the years ahead for the undergrounding of all power supply. Has Mr White considered how his 0.0225 in^2 11 kV solid-insulant-type cable will be connected into an underground 11 kV system? Is he satisfied that fault levels can be controlled to a degree where an 0.0225 in^2 conductor will still be satisfactory?

His comments on buried transformers are of interest. In Wellington we have used the berm-type substation for a number of years and this has found wide acceptance with the public. I agree that the vault-type substation has few real advantages and a great many disadvantages.

One aspect Mr White does appear to have overlooked has been the question of the losses. His economic comparison with conventional three-phase distribution is of interest, and there does not appear to be a great deal in it. I would ask, however, whether the capitalised cost of cable and transformer losses (which Mr White has omitted) might not swing the balance more convincingly one way. As is well known, the losses for single-phase l.v. distribution are greater than for three-phase, and I would like Mr White's comments on these points.

His comment regarding the correct size of l.v. cable is a provocative one. I might be prepared to agree with him if it were possible in Wellington to have trenches excavated, cables laid and the trench back-filled—all for 75c per yard. Because of their difficult ground conditions many supply authorities pay much more than this, and in many cases an economic evaluation would show clearly that the policy adopted in the United Kingdom of providing initially for a period of say 30 years, can be the right one and the cheapest one.

I was interested in his view that cable manufacturing, cable laying and terminating costs are likely to fall in time. We see no real evidence of it.

The rise in a.d.m.d. is an important consideration in the economic forward planning of distribution systems. I believe that apart from the present economic phase, the rise in the a.d.m.d. per consumer will continue and this will tend to decrease the advantages of the single-phase distribution system.

R. P. THOMSON (Otago E.P.B.)—I would like to raise the question of earth-leakage protection on the high-voltage system as detailed in 3.1. That is the system described as the phase-to-neutral system connection of transformers.

We have a small rural set-up working substantially on a single-wire system, the main difference being that the earth-return system is used instead of the h.v. neutral. In the system three single phases are taken off a three-phase isolating transformer. We have found that it is impossible to obtain better than 50% balance under the varying load conditions and this is rather disconcerting.

I would suggest that great difficulties could be experienced in providing the 12% earth-leakage setting as required by the regulations, using the system detailed in the paper, and it would appear rather impracticable if all the transformers on the feeder were connected in this manner. Could Mr White tell us how he intends to overcome that problem?

J. D. ELLIS (Hutt Valley E.P.G.B.)—I am interested in the type of cable Mr White has shown and the jointing techniques. I was also privileged to tour overseas at the same time as Mr White and my very strong impression, particularly with the organisations such as Pujet Sound, was that they would do almost anything to avoid jointing the polythene cross-linked cable. They had the jointing instructions, but any joints were generally made in pits to faciliate easy access. I did not see one nor was I shown one, despite all my asking, directly buried. Indeed, the design engineer said that before they jointed, they even considered whether it would not be cheaper to replace the length of cable!

On the question of u.r.d. in single-phase distribution, maybe there is a big field for the cross-linked polythene eventually, but where three-phase supply is required, with our ground conditions we have to treat this with both great caution and great care.

We have had a good look at this single phase system, but the basis of the American system is the 110 V secondary distribution, and when you compare American economics with ours, you have to look at their whole scheme. With their 110 V secondary distribution they can get away with very much simpler joints on their low-voltage side while they make a few compression joints and wrap them up in a polythene bag. These things go a long way towards a cheaper system.

O. C. STEPHENS (Thames Valley E.P.B.)—I am particularly interested in the type of fusegear illustrated in Fig. 3. What type are these fuses, are they bare or exposed? What are the clearances to earth? What would be safety operating methods from ground level?

It appears to be a pole-mounted type of fuse, converted to pad-mounted use and I would question its operating safety.

E. N. BOOTH (Wanganui-Rangitikei E.P.B.)—If one decides to use the single-phase system, then the methods favoured by Mr White are generally acceptable and soundly based, but in comparing the costs of the three-phase and single-phase systems, the arguments have been biased toward the latter.

No mention has been made of the capitalising losses in cables or transformers and to get some appreciation of the effect of capitalising transformer losses it is interesting to compare the annual cost of three-phase and single-phase transformers supplying a 200 kVA after-diversity maximum demand.

In Table I the Institute formulae, with power costs of $23.5/kW, 0.27c/kWh and a 45% load factor has been used. It was assumed that the single-phase units would share the load equally.

TABLE I

E.S.A.E.I. standard transformer rating	*No. of phases*	*No. of units to supply*	*Total capital cost*	*Annual cost†*
kVA			$	$
200	3	1	863	136
25	1	8*	1,944	252
50	1	4*	1,640	217
75	1	3	1,560	204
125	1	2	1,320	177

†[$(0.9A + 0.0472I + 0.0112c)$]

* In practice additional single-phase units would be required.

This particular aspect of the three-phase-one-phase comparison favours the three-phase underground reticulation system on the two counts of lowest capital cost and lowest annual cost after capitalising losses.

The question of capitalising conductor losses would be tedious to compute, but would probably also favour the case for three-phase underground reticulation.

Would Mr White indicate whether the conductor and transformer losses have been capitalised in his comparison for the three-phase and one-phase systems?

R. W. HUBBARD (Waitemata E.P.B.)—I would agree with Mr White's observations on American practice and disagree with Mr McCutcheon on one particular point with regard to American practice—that single-phase reticulation is generally carried out in exclusive housing areas possibly using one transformer to two houses because of the 110 V reticulation. It is also interesting to record that in America, for the equivalent of group-housing schemes such as State housing schemes in New Zealand, the Americans and Canadians use the overhead and not underground, and this is where Mr White's proposals for the single-phase reticulations would be enormously effective economically in areas of group houses and State houses, which are built and filled immediately and the supply authority can actually calculate with accuracy the load involved in each particular house. However, there are certain limitations which one must expect with single-phase reticulation, and that is in a slow-growing high-class residential area where I would be inclined to recommend three-phase rather than single-phase reticulation. In Auckland this has been borne out in actual practice in some of our East Coast bays, where very high-priced houses have been built and where, after the area has been reticulated underground, some residents have asked for loads of 45 to 50 kW for indoor swimming pools or under-carpet heating. This is a load which would be very difficult to supply single phase, but not so difficult with three phase.

The other tremendous advantage of the single-phase pad-mounted transformer is that it is excellent for hot-stick work. The Americans, and the Canadians, too, replace the single-phase pad-mounted transformer alive, and it is very simple to do this when the reticulation is single-phase. They merely undo one end with a hot-line stick, put an insulated socket over the cable, and the transformer is very easily replaced. It is much more difficult in three-phase systems.

In section 4.2, Mr White does not mention the kilowatt size he is proposing to allow per consumer. Does he propose some form of mid-point connection or l.v. connection box so that in the event of one transformer faulting, he can carry the load by adjacent transformers? How could he integrate a single-phase system with a three-phase one?

In the appendix he lists under transformer groups "Total Cost" and above that "Transformer Cost". Are these assumptions or costs, because I find myself at variance with him on a 100 kVA transformer at $962? Our current purchase price would be about $600. Again I would be at variance with his figure for the 60 kVA size at $1,228; I feel it would be nearer $1,550. In computing the final cost of cost per consumer, a difference of $100 on a 100 kVA transformer could materially affect the whole comparison of single-phase and three-phase reticulation as the transformer is one of the prime costs as far as the total cost of the installation is concerned.

W. G. JOHNSTONE (Christchurch M.E.D.)—My understanding is that the high-voltage polythene-insulated cable has no lead sheath round it. Are the American users completely satisfied with the cable without a metallic protection? Are they satisfied that over a period of time there will be no trouble?

I was puzzled to see a Canadian standard specification on cross-linked polythene cable which listed two types, one ordinary and one with a lead sheath over the cross-linked polythene for use in very damp situations. What is meant by very damp situations?

Mr White mentioned stresses on 30 kV/cm in the polythene. Is this average stress, or is this the maximum he has adjacent to the conductor?

T. E. KELLY (Hawke's Bay E.P.B.)—I rise in defence of our single-phase system, particularly with out-of-balance situations, the effect on the main supply and earth-leakage protection. We have hundreds of transformers on one 11 kV distributor and we have had no difficulty in keeping a reasonable balance.

Mr White has chosen to signify the out-of-balance of the l.v. side at about 1.25 dividing the 10 V drop which is permissible in his system by 1.25 to get the permissible drop, not only in the three-wire system but also in the three-phase system. Some years ago the area boards in the United Kingdom produced figures on this outer voltage, particularly on three-phase, and on the number of houses that Mr White is connecting—their out-of-balance figure was 1.69 or 1.7, which gives a considerably greater voltage drop on the three-phase system. I know nothing about the figures for single-phase three-wire systems but I would have thought that the Americans would have had some comparable investigations. We have very recently confirmed that the British figures are accurate, and I suggest this is the whole crux of Mr White's comparison.

R. J. ADAMS (Waitemata E.P.B.)—The most unusual feature is the use of a single-phase neutral-return h.v. cable. If the neutral is not covered and in direct contact with the ground, then the proposed system would electrically be similar to a single-wire earth-return system. Presumably when application was made under the terms of Electricity Supply Regulation 4, to use the proposed system a definite size of insulation was required over the neutral. What was the insulation value required? Similarly, with the overhead 11 kV lines, where is the neutral return conductor to be run? If it is on the same cross-arm as the 11 kV phase conductors I doubt whether the figure of $2 per consumer would be sufficient to cover the cost of converting existing lines.

Would Mr White briefly describe the method of stress-coning the h.v. screen and neutral at terminations?

Mention is made of the use of an h.v. aluminium conductor having an area of 0.0225 in^2. For this size of conductor, what is the anticipated performance under fault conditions?

Referring to l.v. conductors, the paper calculated sizes required on a volt-drop basis. Was a cross-check made on the basis of losses to make sure that larger cable sizes might not be more economic?

Might I request Mr White to write an article for the *N.Z. Electrical Journal*, devoted to the construction aspects of this type of reticulation.

Finally, I predict that when the final score is announced it may well become evident the use of single-phase reticulation in America is largely due to their use of 110 V.

AUTHOR'S REPLY

N. R. WHITE: In reply to Mr Binns, it is standard practice for all of the earths to be common, high voltage to low voltage, even the telephone service. This will require some negotiation and is something we will take up with the appropriate authorities.

I do not know how they handle integration of single-phase and three-phase in the United States. I never saw any case there but I worked out this simple arrangement as shown. (*Demonstrated*). The only embarrassment would be where you allowed a consumer to use a 460 V motor in the early stages and then later you put him on to a three-phase system.

With regard to crossings every 40 yd, we have had discussions with the territorial authorities, and they like this system. They like trenching on one side of the road, and they like crossing the road in a pipe.

Although in the paper I said road crossings could be done for $44—and we have succeeded in doing them for that—in our estimate we allowed for some contingencies because I made the point that we required good weather conditions and you don't always get them, even in Tauranga. You do therefore have to make provision for some unproductive time, and add something to contingencies for the road crossings.

The random lay question. I have had discussions with the Post Office representative here and had hoped that he would have had the opportunity of making some comment. The Post Office are prepared to try this system out in Tauranga, and I believe they are having a special cable made for the purpose, so that I am looking forward to a combined operation.

We had to build the 33 kV transformer ourselves because I had the utmost difficulty in getting transformer manufacturers interested. We have received "on spec" a 100 kVA transformer from one manufacturer for trial.

I agree with Mr Binns that the whole concept of the underground is only complete when everything is underground. The first step is to go to a pad-mounted transformer because of the ease and lower cost of doing it. Let us deal with one problem at a time. I would like to take the problem of the cable underground first, and then worry about the second one later.

Mr Adams mentioned neutral covering in the United States, but I did not see any case where the neutral was covered except in the systems where cable comes complete-in-duct. This is common but costly. You lay it in the ground inside that duct. It does make it easier to pull the cable out at a later date, and that is the main claim made for it.

With regard to the neutral on the 11 kV we have had extensive earth-return systems, and still have quite a lot in the Tauranga area, and in many cases we do have a fourth wire, a neutral wire, on the top crossarm, so we do not have too many problems. On new ones we have in mind running this neutral conductor lower than the high voltage, but we have not done this yet. This was one of the problems.

I had hoped to come and tell you how we had met all the problems but the cable I had hoped to receive has still not arrived. It has now passed Customs, so it should be here soon.

Mr Adams also asked if I would use a 0.0225 in^2 aluminium. No, certainly not, but we will use 0.0225 in^2 copper for our h.v. cable.

There are various types of stress cones available. (*American and Swedish ones displayed.*) I rather fancy the more elaborate type.

We had a look at the conductor sizes based on capitalisation of losses, but I have reservations on making vital comparisons for anything on a basis of capitalisation losses, because if you look at this very carefully you have so many factors which, if they are to be of any real use, have to be at the same level throughout the life of the plant. For example, bulk supply tariffs would have to be the same, also interest rates and costs of other items, so we have to treat with some reservation the consideration of deciding on plant on capitalisation losses, but we did that because I was so sure that someone would ask this question. The conductor sizes that we used were fairly close to the ones that were decided on the voltage-drop considerations, but I am not suggesting that those are the final answers. I have given the result of our examination of this problem in Tauranga; we do not think that we will get the answer exactly right first time, but we feel we have made a reasonable step forward.

With regard to submitting an article on construction methods, I will be delighted to do that at a later date when we have finished this job.

Mr McCutcheon feels that I am basing all my paper on polythene cable, but I am not really doing that. I do not agree that the Americans go for this system purely because they have a 110/220 V secondary system. I questioned them on this. I agree that the relative costs of the cable, paper *v* polythene, are very important, and I would suggest to Mr McCutcheon that these costs depend largely on the quantities in which you buy this material. It could well be that Wellington would get a far better price than Tauranga when calling tenders for cable.

With regard to this system not being suitable for closely built-up areas, most of you would remember that I showed you slides on my return from overseas, and then said that the houses were so close together that a crane had to be used to lift a transformer from the back of a lot on to the road for replacement.

I believe that single-phase could supply 60 consumers, but I would want to look more closely.

In my examination of the best size of transformer, I have shown it to be approximately 100 kVA. I do have reservations, however, and I believe the figure will be lower. The question of unbalance comes into it, also the costs and the fact that they fluctuate and vary and we must keep an open mind on this.

With regard to the total underground and fusing, they do have fusing vaults in the United States which are suitable for 15 kV. At the Institution of Electrical and Electronic Engineers symposium a number of contributors said there was scope for more development in the form of switching and fusing vaults.

However, I will not have to connect this in underground vaults for the time being, and by the time I get to that desirable stage there will be plenty of plant developed and available.

On the question whether losses "might not swing the balance"—they could, but not on the calculations that we have done so far.

I agree with Mr McCutcheon that variation in trenching costs could quite well mean that this could be acceptable in one area and not in another and we did evaluate this solely for use in our own area.

I agree that, based on "Demand = $2n + 10$" we should have put in a somewhat smaller transformer. This could make a difference in the assessment of what is the best size of transformer, but these are preliminary figures and will vary with differing costs.

With regard to the unbalance at the end of the line, I would not be prepared to say that the 460 V system is suitable for everybody. Mr Kelly is just as convinced that the 230 V secondary system is the best. My main reason for feeling the 230/460 V system is worth a trial is that it is used so successfully by people

who are hard businessmen and who know how to get the most out of a dollar.

Mr Kelly answers Mr Thompson's question on earth-leakage protection. It is not too much of a problem. If 12½% is difficult of attainment he should look at the possibility of increasing the size of his feeder current transfers. We have found that very successful.

Everyone will avoid having a joint in any cable if they can and I certainly plan to have all joints above ground. My answer to Mr Ellis is that I am not scared to have an underground joint if the necessity arises, even if it is one I put in a non-vital place to see what happens! Someone has to start on this. The man who invented the horseless carriage had the same problem. We have to take risks if we are to make any progress. I do not think it is a very serious risk with a ring feed. I would like to put in an underground joint where, if it is going to blow up, it will not cause too much embarrassment and I will learn something from the incident.

In answer to Mr Stephens the fuse is a liquid fuse. Also, Mr Hubbard raised a question in regard to isolation with hot stick equipment, and I have here a Load Buster (*demonstrated*) which is the type used for opening these links. You have one of these for hundreds of transformers. This is the standard method used in the United States for isolating these transformers. It does make for very rapid transformer change and can be done in complete safety.

We have evolved through three stages of l.v. fuse pillars and we are now going to attempt these underground. We have recently introduced a new requirement that all new houses have a small meter box in a specified position for the supply authority equipment, which means we can isolate very simply at the point of entry.

I agree with Mr Hubbard that the system described is best for group houses. Even if it is only suitable for that, it is well worth adopting. I do not agree that three-phase is more suitable for slow growing areas because if you must have plant lying idle, I would prefer single-phase rather than three-phase plant lying idle in the ground.

I intend to have a mid-point connection of transformer areas between each transformer area. It is a continuing process. You put in your transformers as you need to, and it is comparatively easy to put another transformer in the intervening space, as long as you have cross-road crossings for every consumer on every second boundary.

Integration of single-phase and three-phase is not a problem. It would arise only when a housing area is first reticulated with single-phase and later developed into a community area, with shops and garages, which require three-phase supplies. It is simple to use the three-phase transformer to supply single-phase, by taking two of the three phases.

I would not be surprised if Mr Hubbard gets a better transformer price than we do and this could account for the difference between his figure and ours.

Mr Johnston is the first one to suggest that there could be a problem in time in locations where lead sheathing is required, and I will certainly ask that question overseas as it is worth looking into. All the American users seem to be very satisfied with the neutral bare and I understand that the real reason for not having neutrals bare in this country is the risk of corrosion and the possibility that you could completely lose your neutral with perhaps disastrous effects. There may, however, be some compromise.

Mr Johnston asked about the maximum stresses—we took as the maximum stress adjacent to the central conductor and we used the formula $g\text{max} = E/[r \log(e) R/r]$

where E = Phase-to-neutral voltage of conductor

r = Radius of conductor

R = Radius of sheath

$g\text{max}$ = Electrical stress.

The assumption we made that the voltage drop could be taken as 8 V is a shaky one but in the absence of anything better we decided it was a reasonable compromise. There are a lot of compromises here and everyone must evaluate this system for themselves. If I have made everyone think about it, I am well satisfied.

Lastly, I would like to express thanks to my Board for permission to present this paper and to my staff for their assistance.

Opening of conference

THE 38th annual meeting opened at 10.15 a.m. on Monday, 25 September, 1967, in the Winter Garden Cabaret, Christchurch.

The president (C. L. Walter) welcomed all members and representatives, including elected members and invited representatives of other bodies.

The roll showed that 69 member supply authorities were represented by 87 delegates and that one associate member and three consultant members were also present.

NEW MEMBERS AND REPRESENTATIVES

The president announced that A. Buckingham, C. M. Gray and F. Matthewson (all past presidents) had been elected honorary associate life members upon their retirement as representatives and that A. Mill was also granted the status of associate while holding the position of executive director of the Electrical Development Association.

New representatives appointed during the year were:

W. M. Beale, R. L. Bennett, R. S. G. Boyd, P. Cebalo, E. A. Clarke, E. E. Cresswell, G. R. Culling, B. G. Cunningham, D. W. Dowling, A. A. Hall, C. L. Harris, D. W. Harris, B. Heywood, E. D. Hounsell, H. L. Hoy, D. R. Macown, N. S. Macdonald, T. B. Merson, A. Miller, R. E. Mitchell, W. V. Monaghan, E. J. Moore, J. R. Moore, D. E. Norman, T. W. Orr, A. H. Piper, R. J. Ponton, J. C. Rogers, J. A. Torr, A. N. Wakefield, M. J. Walker, S. R. Wilson.

Besides A. Buckingham, C. M. Gray and F. Matthewson, other retirements of representatives during the year included J. M. Bishop (South Canterbury E.P.B.), J. K. Hooker (Wellington M.E.D.) and A. J. Lindsay (Central Waikato E.P.B.).

OBITUARIES

Members stood in silence as a mark of respect to the following former representatives who had died during the year:

R. H. Allan (formerly Wairarapa E.P.B.).

J. R. Bongard (formerly Tauranga E.P.B.).

W. H. Gregory (formerly Heathcote Co.C.).

APPROVAL OF MINUTES

The minutes of the 1966 annual general meeting, having been circulated in the *Transactions,* Vol. 36, were taken as read and adopted on the motion of the president, seconded by M. G. Keys.

REPORT OF EXECUTIVE COMMITTEE

The president, seconded by S. R. Anstice, moved the adoption of the report of the Executive Committee.

The secretary read a letter from the General Manager, N.Z. Electricity Department on the subject of apprentice training, saying, *inter alia*:

"The officer acting as secretary to the committee left the Department . . .

"About this time, early 1965, the Government set up a Commission of Enquiry into Vocational Training which reported in October 1965. Most of the groups represented on the committee gave evidence to this Commission. It is fair to say that the committee's work greatly aided this action.

"You will receive from me a report on studies carried out by the Electricians Registration Board covering registration. Again information collected for the committee has been of assistance.

"It is clear that the committee did do useful work but that due to an unfortunate chain of circumstances its studies were not completed.

"In view of all the circumstances I suggest that, as the sponsoring body, the N.Z. Institute of Electricians should disband the committee set up in November 1963 as other bodies have done, or in the near future will be doing, the work it was set up to."

The motion to adopt the report was then carried.

ANNUAL ACCOUNTS

The president, moving the adoption of the annual accounts and balance sheet, drew attention to the fact that the excess of expenditure over income was almost £82. There had been no major publications, and the profit from their sales had not been adequate to cover the cost of the *Transactions.*

For the first time the cost of the *Transactions* had been shown separately from other publications. Profit from sales of publications had been £202, whereas the net cost of the *Transactions* was £226. The amount in the World Power Conference Fund had been just sufficient to cover the costs in connection with the Tokyo Sectional Meeting.

The motion was seconded by M. G. Keys and carried.

REPORTS OF REPRESENTATIVES AND COMMITTEES

The president, seconded by J. D. Ellis, moved the adoption of reports and after some discussion* the motion was carried.

Mr Ellis (Hutt Valley) seconded.

* See p. 83.

Report of Executive Committee

(Covering the period 1 September 1966 to 31 August 1967)

FULL-day executive meetings were held in Wellington on 30 November, 1966, 17 February, 26 April and 22 August, 1967.

1966 CONFERENCE RECOMMENDATIONS

Apprentice training

The mover of the conference resolution supplied details of his proposals and the information was referred to the N.Z. Electrical Supply Authorities Industrial Union of Employers to take up with the Department of Education.

Statistics committee

The Electrical Supply Authorities Association agreed that the report might be further considered and said that the Association would appreciate any further advice.

Injection-frequency control relays

The resolution was referred to the Electrical Supply Authorities Association who took the matter up most strongly with the Minister of Industries and Commerce.

Institute award

The president presented the 1966 award to R. M. O'Callahan at a meeting of the Hutt Valley E.P.G.B. on 16 February 1967.

ADMINISTRATION

Accounts

Although income from subscriptions increased by £142, total subscription income (£1,607) was, as usual, insufficient to meet the costs of running the Institute (£1,973). With no major publications during the year, the profit from sales of all publications (£202) did not even cover the net cost of the *Transactions* (£226). Miscellaneous sources of income (interest £74, and film hire £9) were insufficient to offset the deficiency so that it was necessary to draw on accumulated funds by £82, reducing them to £1,106.

The World Power Conference Fund was just adequate to cover the costs of assisting the president's attendance at the Tokyo Sectional Meeting and also of paying the registration fee of the author of the supply authority paper.

Since 31 March, and after discussions with the president of the Electrical Supply Authorities Association, the decision has been taken to refund to the supply authorities concerned, expenses incurred for the attendance at executive meetings of those representatives who are members of the executive. It is hoped to be able to do this without increasing the basis for the Institute subscription which for some time has been one-eighth of the Association subscription.

Publications

The *Transactions* Volume 36 were supplied free to all members and representatives and reprints of extensive reports on the Tokyo Sectional Meeting of the World Power Conference and the New Zealand "Electronics for Export" conference (both written by the Institute secretary) were supplied for the information of chairmen.

Except for a reprint of the Code of Domestic Electrical Installations (for which there has been a steady demand) there were no publications during the financial year ended 31 March 1967.

The new editions of the Lineman's Handbook and the Safety Manual, however were passed for printing subject to approval of the Safety Rules by the General Manager, N.Z. Electricity Department and by representatives of the workers' unions. Printing of both publications is now held up pending a reply from the latter.

Earlier in the year the flow of contributions to the *N.Z. Electrical Journal* dwindled and over the whole year only half as many contributions as last year were received. No new histories came to hand. This is most unsatisfactory and is particularly unfortunate as an increasing number of elected representatives are receiving the journal.

Since 1 April 10 codes of practice to accompany the Electrical Supply Regulations 1967 and a book of sag tension charts have been approved for publication and all of these will appear prior to the 1967 conference.

Membership

During the year three past presidents —A. Buckingham, C. M. Gray and F. Matthewson—who had retired as representatives, were elected honorary associate life members, while the newly appointed executive director of the Electrical Development Association—A. Mill, also a former representative— has been elected an associate member for the period of his E.D.A. appointment.

A consultant member (B. H. Goldsmith) retired from active practice and regained the status of associate membership which he had held previously.

One new consultant member (I. R. Densem) was admitted.

Present membership totals are:

Supply authorities 72.
Consulting engineers 6.
Associate members 13.

There are 153 supply authority representatives appointed.

Secretariat

Organising 32 persons to the Tokyo Sectional Meeting of the World Power Conference and conducting them throughout the 25-day Institute-sponsored tour was an extra task for the secrtary, and one which involved him in an immense amount of time during the latter part of 1966.

The editing of the revised edition of the Lineman's Handbook and the Safety Manual were additional jobs for the secretary and his staff and, as well as those major publications, a further 11 new Institute publications are being printed and sold.

In the midst of these activities the Institute's second management seminar was staged and although this normally involves the secretariat in little additional work, on this occasion a number of last-minute problems occurred, involving the preparation and delivery of an address by the secretary at 48 hours' notice.

Meanwhile his routine activities such as attendance at all regional meetings have continued.

Without doubt the secretary and his extremely limited but very capable staff have had a hectic year—one in which the Institute has established new publishing records, the financial rewards of which will be spread over several years ahead.

OTHER MATTERS

Rationalisation of materials and methods

At its first meeting the Institute executive endorsed the recommendations of the Electrical Supply Authorities Association Committee to Investigate Savings Through Co-operation and suggested that standardisation of materials was the field in which the greatest savings could be made. The executive considered that regional committees dealing with separate items of equipment should be set up in an endeavour to reach some rationalisation which could be extended from time to time and it felt that the bulk buying of standardised equipment would be a natural consequence of this.

Since then a rationalised schedule of requirements for aluminium conductors has been prepared, circulated and considered and is about to be recirculated in amended form. The standard schedule for distribution transformers is also

THE ELECTRIC SUPPLY AUTHORITY ENGINEERS' INSTITUTE OF NEW ZEALAND INC.
BALANCE SHEET—As at 31 March 1967

1966 £		£ s. d.	£ s. d.
	Current liabilities		
20	Sundry creditors	—	
74	Northern region linemen's prize fund	73 15 9	
47	Central region linemen's prize fund	41 6 0	
330	World Power Conference fund	7 3 11	
471	*Total current liabilities*		122 5 8
	Accumulated funds		
1,179	Balance at 1 April 1966 ..	1,187 12 0	
9	*Less* excess of expenditure over income	81 15 6	
1,188	*Total accumulated funds*		1,105 16 6
£1,659			£1,228 2 2

1966 £		£ s. d.	£ s. d.
	Current assets		
2	Cash on hand	2 0 0	
554	National Bank of N.Z. Ltd.	116 5 6	
48	Post Office Savings Bank	68 1 2	
14	Sundry Debtors	16 16 4	
618	*Total current assets*		203 3 0
	Investments		
500	N.Z. Government Stock .... (approx. market value)	500 0 0	
460	Post Office Savings Bank —Investment account	460 0 0	
960	*Total investments*		960 0 0
	Fixed assets (at cost less depreciation)		
81	Office equipment		64 19 2
£1,659			£1,228 2 2

REPORT OF THE AUDITORS TO THE MEMBERS OF THE ELECTRIC SUPPLY AUTHORITY ENGINEERS' INSTITUTE OF NEW ZEALAND INC.

We report that we have audited the books and accounts of the Electric Supply Authority Engineers' Institute of New Zealand Inc. for the year ended 31 March 1967. We have obtained all the information and explanations we have required. In our opinion, the above Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs as at 31 March 1967, according to the best of our information and the explanations given to us and as shown by the books of the Institute.

Wellington, N.Z.,
16 May 1967.

CLARKE, MENZIES & CO.,
Public Accountants.
Auditors.

STATEMENT OF RECEIPTS AND PAYMENTS—For the year ended 31 March 1967

RECEIPTS

1966 £		£ s. d.
418	Balance	553 6 6
1,465	Subscriptions	1,606 11 0
275	Publications	398 14 4
—	*Transactions*	79 14 7
10	Annual conference	25 2 7
54	Interest	53 13 3
3	General expenses	4 6 3
441	Management seminar	—
128	Overpayment of subscriptions	2 12 4
132	Film account	9 0 0
4	Postages	1 12 6
6	Travelling expenses	—
—	World Power Conference	650 8 0
£2,936		£3,385 1 4

PAYMENTS

1966 £		£ s. d.
283	Publications	186 0 2
—	*Transactions*	309 17 8
209	Annual conference	428 13 0
71	Regional meetings	88 9 1
950	Secretarial fee	987 10 0
26	General expenses	41 5 5
81	Postages	97 14 7
112	Printing and stationery	83 2 6
11	Audit fee	10 10 0
62	Film account	—
32	Travelling expenses	13 17 0
417	Management seminar	—
1	Central region prize fund	6 0 0
—	World Power Conference	973 4 1
—	World Power Conference subscription	40 0 0
128	Subscriptions (refund of overpayments)	2 12 4
553	Balance	116 5 6
£2,936		£3,385 1 4

INCOME AND EXPENDITURE ACCOUNT—For the year ended 31 March 1967

EXPENDITURE

1966 £		£ s. d.
199	Annual conference	413 10 5
71	Regional meetings	78 9 1
950	Secretarial fee	987 10 0
22	General expenses	36 19 2
78	Postages	95 18 10
106	Printing and stationery	73 4 6
11	Audit fee	10 10 0
27	Travelling	13 17 0
20	Depreciation	16 4 10
80	World Power Conference fund	—
20	World Power Conference subscription	20 0 0
30	Publications	—
—	*Transactions*	226 7 6
9	Excess of income over expenditure	—
£1,623		£1,972 11 4

INCOME

1966 £		£ s. d.
1,465	Subscriptions	1,606 11 0
—	Publications	201 13 11
61	Film hire	9 0 0
73	Interest	73 10 11
24	Management seminar	—
—	Excess of expenditure over income	81 15 6
£1,623		£1,972 11 4

being reviewed while the 10 codes of practice to accompany the supply regulations and the Sag Tension Charts all contribute to further rationalisation.

The Institute president has discussed with the Waikato Master Builders the possibility of rationalisation of meter box sizes.

The Electrical Supply Authorities Association's Materials and Import Licensing Committee has suggested further work that might be undertaken by the Institute but the executive considers that for the time being it is not practical for the Institute to do much more in the rationalisation of construction methods.

Research papers and articles

At the request of the executive director of the Electrical Development Association, regions were asked whether special reports, particularly on space-heating and electric-range usage, could be prepared, and it is hoped that such reports will be forthcoming.

Cross linked polyethylene cables

At the request of a member supply authority, extensive information was obtained from overseas on this new type of cable insulation and a report made to the Electrical Supply Authorities Association and to all members.

University training of supply authority electrical engineers

A sub-committee was set up to consider the university training of electrical engineers with particular reference to their future employment in the electric supply industry. The views of both the Auckland and National Schools of Engineering were obtained and the head of the Department of Electrical Engineering of the National School has been asked to address the forthcoming conference.

Safety training and instruction

At the request of the General Manager, N.Z. Electricity Department, the Institute's Safety Rules and Lineman's Handbook were reconsidered to see whether the section dealing with the operation of e.h.v. and h.v. airbreak switches required amendment. It was agreed that no amendment to these publications was required but that a code of practice might be contemplated.

A circular issued by the Electricity Authority of New South Wales on earthing of pole-mounted airbreak-switch handles and the operation of airbreak switches by persons on poles was referred to regions for their information.

The executive has again been concerned by the continued operation of cranes and similar equipment near power lines. It is felt that prosecution of offending operators is the only effective deterrent.

An Institute Committee is preparing a comprehensive code of practice for live-line working.

Three prints of the Linemen Training Film are available for general safety-training purposes.

Liaison with Australia

Liaison has continued with the Electric Supply Authority Engineers' Association of Australia and with Australian supply authorities in general. An Institute executive member, W. M. E. Mirams, was one of the Electrical Supply Authority Association's two representatives to Australia in May 1967.

World Power Conference

Potential authors and probable participants in the Eighth World Power Conference, Moscow, 20-25 August 1968, have been kept informed of proposals and developments. A paper by an associate member has been accepted for presentation.

Regulations

The revised Electrical Supply Regulations have attracted considerable criticism and an opportunity to discuss specific regulations will be given at the Institute conference.

Standards Association

Except for the usual activities of representatives on Standards Association committees there has been little contact between the executive and the Association during the past 12 months but the change from the old Standards Institute to the new Standards Association is undoubtedly an improvement.

Committees and representatives

Institute committees and representatives for 1966-67 were appointed and all their attached reports tabled at an executive meeting.

In response to requests from the Electrical Supply Authorities Association the following nominations were made:

Bursary and Travel Award: G. H. Battersby.

Conciliation Committee: J. K. Hooker.

Legislative Watch Committee: C. L. Walter.

Materials and Import Licensing Committee: J. K. Hooker and R. W. Hubbard.

Natural Gas Committee: S. R. Anstice and W. M. E. Mirams.

Power and Finance Utilisation Committee: S. R. Anstice, J. D. Ellis and W. M. E. Mirams.

R.E.R.C. Ceiling Costs Revision Committee: J. W. Rogers and K. A. Wilson.

Road Safety Committee: J. D. Ellis.

Tariff Committee: T. E. Kelly and S. E. Slatter.

Trees Committee: J. A. Warner.

Nominations to Union committees were made as under:

Accident Prevention: T. H. Watson and J. E. Coghlan.

Cable Jointers: S. R. Anstice, J. K. Hooker, M. G. Keys, W. M. E. Mirams, L. E. Rasmussen and K. A. Wilson.

Globo: K. A. Wilson.

Live-line Working: J. D. Ellis.

Electrical Supply Authorities Association

The Association asked urgently for a report on power supply and this was provided by the Institute's special committee. Other matters referred to the Association concerned a decision of the Town and Country Planning Appeal Board and the proposal for local manufacture of 11 kV switchgear.

Three informal meetings were held between the president of the Electrical Supply Authorities Association and the Institute president in order to assist the liaison between the two bodies. One of the results of these meetings has been the executive's request for Institute representatives on Association committees to report regularly to the Institute secretary. Another innovation has been the supply to the Association of a summary of the matters discussed at each executive meeting and publication of that summary in the *N.Z. Electrical Journal* for the information of all members.

Liaison with the Secretaries Association has continued and it seems as though the joint conference session with speakers of common interest will be carried on indefinitely.

Electrical Development Association

S. R. Anstice was nominated to act as deputy to O. C. Stephens as engineer-director.

Miscellaneous Institute matters

Miscellaneous matters considered during the year included:

Conditions of appointment: Revised conditions for local bodies, drafted by the N.Z. Institution of Engineers, were examined and approved.

Bacterial attack on p.v.c.: Certain statements were referred to the Physics and Engineering Laboratory who replied that there was no need to condemn p.v.c. on this score.

Caravan warrants: All member authorities were asked to enforce the requirements and the General Manager, N.Z. Electricity Department, was asked to advise camping-ground owners accordingly.

Fluorescent lamp ballasts: An indication of the cost of making all ballasts high-audio-impedance types was obtained from the manufacturer and supplied to all regions for their information.

1967 conference: The executive invited papers and selected addresses to be given to the Institute conference and to the joint meeting with the secretaries.

National Appeal Authority: The executive advised the Employers' Union that it could not support proposed legislation for a national authority.

N.Z.E.D. points of supply: The committee set up to define a common policy has presented its preliminary report.

Bell transformers: Cases of serious overheating were referred to the executive and the member was advised to take them up with the General Manager, N.Z. Electricity Department.

Testing of rubber gloves. The question of a code of practice is under consideration.

Nominations for officers: The Executive Committee made the following nominations for the 1967-68 officers:

President: S. R. Anstice.

First vice-president: M. G. Keys.

Second vice-president: W. M. E. Mirams.

* * *

Many of the above items are dealt with more fully in the accompanying reports of representatives and committees.

C. L. WALTER,
President.

Reports of Representatives

ELECTRIC LINEMEN TRAINING COMMITTEE

THE committee met on four occasions at regular intervals during the year.

Amendments to the Electric Linemen Act 1959, forecast in last year's report, which were gazetted in October 1966, simplified the processes necessary to allow a lineman to resume his duties as a certificated lineman after non-compliance with certain of the requirements of the Act.

Statistical information relative to the committee's activities during the year is set out in Table I:

TABLE I—STATISTICAL INFORMATION

Meetings held	4
Candidates granted Certificates of Competency:	
Section 14	166
Section 15 (1) (b)	4
Section 15 (1) (c)	1
Examinations held	16
Candidates passed examinations	213
Percentage passes—oral	90.3
Percentage passes—practical	94.1
Visits to examinations by Committee	9
Totals since introduction of Electric Linemen Act and Regulations	
Certificates granted:	
Section 14	1033
Section 15(1)(a)	1068
Section 15(1)(b)	332
Section 15(1)(c)	18
Examinations held	118
Candidates passed examinations	1356
Approved schools	29

S. R. ANSTICE
W. M. E. MIRAMS

ELECTRICAL REGULATIONS ADVISORY COMMITTEE

No meetings have been held. It would appear that this committee is actually defunct, particularly now that the Electrical Supply Regulations 1967 have been established.

T. E. KELLY
A. MILL

ELECTRICAL WIRING REGULATIONS COMMITTEE

This committee has met regularly throughout the year, and the results of the deliberations have been made known to all interested by means of information circulars, publicity in the trade journals, and in special cases by circular letter.

Most of the alterations made, or the interpretations given, are obvious and need no further comment. Amendments to Regulation 93 (flammable and explosive conditions) were made in line with amended requirements of other interested parties.

The alteration to Regulation 152 (earth-continuity conductors) requiring all exposed earthing leads behind accessories and switchboards to be insulated, is aimed at removing the cause of several fires and cases of electric shock. A logical development from this should be that the earthing core will be insulated in exactly the same way as the other cores. There is still a tendency by some to treat the earthing conductor as of less importance than the others, and to overlook what may occur under various fault conditions.

Enquiries were made regarding methods used to supply cattle prodders in abattoirs and slaughterhouse yards, to ensure adequate safety to persons. Four methods quoted appeared to be giving satisfactory results, and were quite safe to operate, yet did not upset the cattle and affect the quality of the meat. These were:

(1) Voltages up to 110 V isolated from earth, supplied through transformers and applied by two prongs.

(2) Ignition coils and systems operated from 230/6 to 8 V transformers and having one pole earthed.

(3) As (2) but operated from secondary batteries.

(4) Motor-driven magnetos having one pole earthed.

The introduction of non-metallic waste pipes has made it necessary to consider further the question of bonding exposed metal in bathrooms. Tests are at present being carried out on the conductivity of water samples from various sources.

A request from the N.Z. Institute of Electricians that it be made mandatory to provide an earth peg on every consumer's installation was referred to all supply authorities for comments. Only 28 replies were received, of whom 26 favoured the proposal. The poor response was disappointing, but the results of tests made by one authority raised considerable doubts about the effectiveness of such pegs, at least in some areas. It is not intended to amend the regulation at present, it being left to each supply authority, which should know best the earthing conditions in its area, to make any local requirement considered necessary.

It was also suggested that there could be need for more care and attention to the distribution- and service-line neutrals, particularly at joints.

The 14th edition of the I.E.E. regulations has been issued, and permission granted to use the current ratings given in the tables therein, subject to compliance with all the other relevant conditions. Although at first glance there was considerable up-rating of many cables, other factors such as grouping, bunching, ambient temperature, are such that in many cases there is little final gain. Another factor sometimes overlooked with the up-rating is the much more severe voltage-drop figure, which in the case of lighting and of heating circuits can cause dissatisfaction.

The committee are now engaged on a complete review of the "Handbook" to the Electrical Wiring Regulations 1961 in the light of experience gained, questions asked and the 14th edition of the I.E.E. regulations. Comments and suggestions from members are invited, and will be given full consideration.

A. MILL

CODES OF PRACTICE COMMITTEE

The "Code for domestic installations" has proved most popular, and has received considerable publicity both in New Zealand and overseas.

The draft "Code on testing and inspecting of consumer installations" was considered very fully at a meeting of the committee. The original draft was expanded, and the scope extended, to give a broader application. It is hoped that this can be completed in the near future.

Other codes were being prepared by sub-committees set up in other centres, but they appeared to be making very little progress.

During the year C. C. Kenward, who represented the N.Z. Institute of Electricians, was replaced by I. Webster.

A. MILL

ELECTRICIANS REGISTRATION BOARD

This report covers the year ending 31 March 1967. During this period the Board held 12 full-day meetings.

Amendments to the Act will facilitate administration, recognise overseas experience for registration as inspectors and extend the Board's disciplinary powers in respect to defective work.

Active cooperation with the New Zealand Trades Certification Board has continued. Examinations in electrical fitting have been introduced for government apprentices and it is expected that revised prescriptions for electricians including a Second Qualifying examination will apply in 1968.

Close liaison has been maintained with New Zealand apprenticeship committees and the effect on registration requirements of major amendments to the Electrical Trades Apprenticeship Order is under consideration.

From the statistics shown in this report it will be noted there is an increase of 12% in the registrations for electricians compared with the previous year, but this is still, at least, about 12% short of the requirements for the whole of the electrical industry.

While the work of the Board is increasing a lot of time has been usefully spent in having a careful and detailed look at all forms of registration, but this requires a lot more consideration.

It has been possible, however, to find a method which will combine the large number of examination papers into one common paper for all limited registration candidates. It is important that engineers should know exactly what the changes are, and be able to advise their staff of the new requirements. It is recommended that all supply authority engineering staff should carefully read and study the advice published in the trade press journals under the heading of "Limited Registration examinations".

The new arrangements in brief are:

Commencing in October there will be one limited registration written examination of three hours duration to replace all present limited registration papers. (Seven in all.)

The "Handbook" to the Electrical Wiring Regulations 1961 will be permitted in the examination room and will be essential for answering questions on regulations.

Candidates are expected to bring their own handbooks to the examination room.

The new written paper will be in two parts:

Part 1 will contain a number of questions without options. Some of these questions will be on electrical wiring Regulations requiring short answers to be filled in by the candidate.

Other questions will relate to the understanding of the regulations, to safe working practices and their applications in limited electrical servicing work.

Part 2 will contain a number of questions with options on simple electrical theory and its general applications making a total of 10 questions to be answered for the paper.

The present examination syllabus will continue to be the basis of the new paper. The standard of the paper will relate generally to the various papers in use in the past with particular emphasis on safe working practices.

The limited registration practical examination will continue as at present.

Anyone requiring further information should communicate with the Registrar of the Electricians Registration Board.

Prizewinners

Candidates obtaining the highest marks were:

April 1966 examination (practical)

M. K. Browning, c/o 21 Wendover Street, Papanui, Christchurch (96 out of (100). Employed as an apprentice by D. G. Tohill, Papanui.

STATISTICS RELATING TO ELECTRICIANS REGISTRATION BOARD
(Year ended 31 March 1967)

(The figures in parentheses as for the previous year)

Registrations	*During year*	*Total*	*Current*
Inspectors	53 (48)	1,062 (1,009)	608 (604)
Electricians	542 (483)	10,834 (10,292)	10,497 (10,025)
Electrical servicemen	12 (11)	500 (488)	442 (435)
Electrical (radio) servicemen	160 (167)	2,120 (1,960)	2,076 (1,920)
Limited Registration (1)	180 (193)	3,227 (3,047)	2,803 (2,674)
Provisional licences (2)	665 (553)	5,386 (4,721)	
Permits to assist	118 (209)	1,848 (1,730)	
Applications for ruling on experience	161 (202)		

Examinations	*Candidates*	*Passed %*	*Highest marks*
Electricians and electrical servicemens written, theory paper	870 (747)	65 (65)	97 (96)
Electricians and electrical servicemens regulations paper	838 (702)	82 (74)	100 (100)
Electricians and electrical servicemens practical (two examinations)	985 (914)	73 (63)	96 (96)
Radio servicemen and limited registration, written	638 (605)	87 (73)	98 (95)
Electrical servicemen and limited registration, practical (two examinations)	524 (489)	81 (76)	96 (91)

Breaches of Act reports 20 (7); *Prosecutions authorised* 11 (1)
Defective work reports 6 (1); *letter of censure* 2; *warning* 1; *insufficient evidence* 1; *action incomplete* 2.

October 1966 examinations (written and practical)

Written paper (theory)

B. Devitt, 45 Totara Street, Ravensbourne, Dunedin (96 out of 100). Employed as an apprentice by N.Z. Railways, Dunedin.

Practical exercise

W. P. Eyles, 14 Mary Street, Blenheim (95 out of 100). Employed as an apprentice by R. Cresswell & Sons Ltd., Blenheim.

Associated British Cables Ltd., Christchurch, continued to award gold medals to the candidates who gained highest marks, and the proprietors of the *N.Z. Electrical Journal* presented copies of the *Journal* for 12 months to the prize-winners, all from the South Island.

General

The Board has been of assistance to supply authorities in many ways. It has been able to continue the service of sending the Registrar (E. M. Brown) or his deputy (H. Buchanan) to assist with apprenticeship schemes, cases of prosecution, breaches of Act, defective work and other matters.

C. O. Larsen, as the representative from the Electrical Workers Union, was appointed to the Board in July 1966.

The appreciation of this Institutte is again recorded for the work carried out for the electrical industry by the N.Z. Electricity Department, the Registrar, his deputy and staff.

H. B. KEENAN

N.Z. ELECTRICAL TRADES APPRENTICESHIP COMMITTEE

Three meetings have been held during the year. The original proposal put forward to meet the altered conditions for apprentices were not acceptable to all, but finally a modified proposal was accepted, and came into force early this year. Wage rates adopted were closely in line with those of most other industries.

Bonuses for passing examinations have been removed, but a credit in time (with the consequential rise) provides a strong inducement to study, and also enables the more capable apprentice to complete his training and experience in a shorter time than the one who is slower, but not necessarily inferior.

Initially these alterations (except the wages) were only applied to new contracts entered into after the order came into force, but now an application has been made so that this can apply (as after December 1967) to existing contracts. This delay was adopted to avoid undue embarrassment to employers who could have, with no prior notice, lost all their senior apprentices overnight.

When certain other modifications now being considered are clarified, it is proposed to consolidate the Apprenticeship Order in its entirety.

With these shortened terms of apprenticeship, which could be as short as 7,500 hours, the Electricians Registration Board still adheres in principle to the concept of 10,000 hours' experience before full registration. It is at present considering the possibility of some form of apprenticeship registration, or provisional licence, to cover the period from when the examination is passed until the completion, not of the apprenticeship term, but of a minimum basic period of experience.

Another anomaly which has been found, and which could apply particularly to supply authority apprentices, is that in the shortened term, there is no provision made for successes in the Certificate of Engineering examination, and yet there is for the less difficult Advanced Trades Paper "A". The interested organisations are being asked their views on granting a similar concession to the Certificate of Engineering students.

With the exception of Auckland, there was a growing desire to take advantage of the block courses now available in several centres. These courses are supplementary to the local classes, or correspondence courses. The New Zealand committee has reaffirmed its opinion that the block courses are better than other forms of day training, but is not proposing to force such classes where satisfactory training by other classes can be given.

The new prescription for the various trades examinations will come into force for the 1968 courses when it is also hoped to introduce the second qualifying examination.

Doubts were expressed by some local committees regarding the adequacy of experience being obtained by apprentices in some rather specialised industries. The Electricians Registration Board was asked to define in more precise terms the requirements as set out in the "list of skills to be taught" incorporated in the Order. This the Board did not want to do, as it feared any such definitions could be restrictive. Others were concerned that whereas "wiring" experience was emphasised, no attention, or not sufficient attention, was paid to that of repairs and servicing of appliances.

During the year A. G. Ash and E. T. Roberts (electrical contractor representatives) whose term had expired, were replaced by A. J. Hislop and J. F. R. Cotter, and at the last meeting J. R. Houston resigned for personal reasons. Their services to the industry cannot be readily assessed. The result of their efforts is to be seen in the conditions of training and of service which apply in our industry today.

A. MILL

N.Z. TRADES CERTIFICATION BOARD ELECTRICAL EXAMINATIONS

The prescriptions committee for the examinations in the electrical trade, for electricians and electrical servicemen, has now completed the revision of the syllabus.

The examinations for the first qualifying, trade certificate and the advanced trade certificate have all been revised. A new examination, to be known as the second qualifying, has been introduced. This examination will be used in 1968 for all apprentices who have passed the first qualifying examination.

T. H. WATSON

RADIO INTERFERENCE ADVISORY COMMITTEE

As there were no controversial radio or television interference problems for discussion the usual yearly meeting was not held.

An inspection of the summary of power line faults shows, however, that there is still a major problem in the interference caused by disc insulators used in the strain position. In the case of radio interference, the 1966 figure was 466 as compared with 272 in 1965. With television interference, the 1966 figure was 983 compared with 1770 in 1965.

It is obvious, therefore that supply authorities should continue to be aware of the problems that they can cause to consumers in this way and improved workmanship with this item of construction is essential.

Tie wires and binders are in their way also more troublesome than they should be.

J. K. HOOKER

Radio interference complaints

(For years ending 31 December 1965 and 1966)

SUMMARY OF POWER LINE FAULTS

High-voltage systems *Lines controlled by supply authorities*	1965	1966
Broken and defective insulators	39	51
Disc strain insulators	272	466
Salt deposit	13	6
Faulty transformers	5	3
Faulty cutouts and fuses	42	40

Faulty air-break switches	8	8
Faulty oil-break switches	—	3
Loose hardware	39	43
Lines off insulators	4	7
Faulty tie wires	65	41
Line contacts	3	13
Faulty lightning arresters	15	9
Faulty transformer bushes	2	3
Oxidised aluminium line connectors	29	13
Stray wire over lines	5	5
Loose or faulty jumper wires	—	5
Trees contacting lines	3	3
Street lighting faults	2	—
Lines in close proximity to dwellings	1	—
Line connectors	1	20
Kidney strain insulators	12	52
	560	791
Low-voltage systems		
Loose connectors	13	5
Neutral broken	5	4
Street lighting faults	7	49
Lines contacting	6	5
Faulty pole cutouts	25	20
Trees contacting lines	2	1
Lines off insulators	—	3
Dry joints	3	—
Low-voltage at peak periods	3	2
Broken and defective insulators	3	—
Bias control relays	8	2
Underground mains	3	—
Stray wire over lines	1	1
	79	92
Lighting		
Fluorescent	271	157
Incandescent	2	6
Mercury and sodium	81	14
Neon	10	10
	364	187

Television interference complaints

(For years ending 31 December 1965 and 1966

SUMMARY OF POWER LINE FAULTS

High-voltage systems		
Lines controlled by supply authorities	1965	1966
Broken and defective insulators	150	57
Disc strain insulators	1770	983
Salt deposit	76	71
Faulty transformers	4	—
Faulty cutouts and fuses	91	28
Faulty air-break switches	35	14
Faulty oil-break switches	—	—
Loose hardware	378	68
Faulty tie wires and binders	649	134
Line contacts	—	4
Faulty lightning arresters	4	2
Noise and interference due to line reconstruction	—	—
Stray wire over lines	11	5
Loose or faulty jumper wires and connectors	—	2
Trees contacting lines	4	2
Street lighting faults	5	1
Faulty line clamps	16	16
Lines in close proximity to dwellings	5	—
Sparking kidney insulator shackles	107	54
Faulty kidney insulators	—	—
Lines off insulators	6	9
Faulty transformer bushings	1	—
	3312	1450
Low-voltage systems		
Loose connectors	27	3
Neutral broken	3	3
Street lighting faults	32	43
Lines contacting	3	1
Faulty pole cutouts	15	2
Faulty switches	—	—
Trees contacting lines	1	1
Low voltage peak periods	51	59
Stray wire over lines	—	—
Broken and defective insulators	1	—
Lines off insulator	1	1
	134	113
Lighting		
Fluorescent	25	1
Incandescent	19	1
Mercury and sodium	10	—
Neon	5	—
	59	2

ELECTRICAL SAFETY COMMITTEE

This committee of the National Safety Association has held quarterly meetings during the year and in addition the Wellington members have held several subcommittee meetings.

The pictorial "annual notice to consumers" was again in demand and 602,000 copies were ordered by supply authorities during 1966. A new colour printing format has been produced for the 1967 publication and the style of notice improved.

The committee is, as an experiment, sponsoring a scholarship to the Outward Bound Training School for one electrical apprentice from the supply industry. The successful apprentice will attend the November course.

The booklet *This could save a life* was well received and following the free distribution of the first 10,000 copies a further 50,000 copies were ordered by various supply authorities.

The National Safety Association has conferred on A. Buckingham its award of merit in recognition of his outstanding contribution to accident promotion. Mr Buckingham recently retired as chairman of the committee after a continuous chairmanship since 1954.

T. H. WATSON

N.Z. NATIONAL COMMITTEE WORLD POWER CONFERENCE

The Electric Supply Authority Engineers' Institute was represented at the Tokyo Section meeting (16-20 October 1966) by 12 supply authority engineers including the Institute president, C. L. Walter. Among the 166 papers presented were two from New Zealand, one prepared by M. D. Macphee (chief engineer, Manawatu-Oroua E.P.B.), the other by E. B. Mackenzie (General Manager, N.Z. Electricity Department).

Apart from the conference proceedings those attending from New Zealand found the technical visits and the informal discussions with representatives from other countries of very great value. Considerable interest is being shown in the next Plenary Session to be held in Moscow 20-25 August 1968, and it is hoped that a number of supply authority engineers will be able to take advantage of this opportunity to keep in touch with progress at the international level.

The New Zealand National Committee met in Wellington on 21 March 1967 and received advice that it was likely that New Zealand would be able to provide its quota of two papers for the Moscow meeting.

Among points discussed was the reimbursement of the costs of printing papers submitted through the New Zealand National Committee. The meeting agreed that in view of its limited funds it would be necessary, in all but exceptional cases, for the committee to continue, at least in the meantime, with the present practice of passing these costs on to the authors of the papers.

S. R. ANSTICE

Standards Association

ELECTRICAL SECTIONAL COMMITTEE

MEETINGS of the committee were held on 12 December 1966 and 22 May 1967.

During the year the N.Z. Standards Association, now independent of Government, moved to leased premises in Hooson's Building, corner Courtenay Place and Tory Street, and G. H. Edwards was appointed director and E. H. Hitchcock, chief technical adviser.

These changes should enable the Association to make sound and steady progress in the future and give improved service to the New Zealand community.

A wide range of topics was dealt with at the two meetings. It included a number of drafts and amendments that were recommended for adoption as New Zealand Standard Specifications, in particular, one covering hard-drawn copper conductors for overhead power lines superseding NZSS 64:1961.

Other items of interest to the electrical supply industry that were given consideration included flammability tests on electric blankets, water-absorption tests on p.v.c.-insulated cables, the preparation of a code of practice for underground jointing of p.v.c.-insulated cables, the need for a specification for electrical equipment to be used in combustible dust atmospheres, and the representation of electrical interests on the Drawing Office Practice Committee.

R. M. O'CALLAHAN
I. A. MCCUTCHEON

ELECTRICAL APPLIANCES AND ACCESSORIES COMMITTEE

Two meetings of the full committee were held—in August 1966 and February 1967. The February meeting was held in the new premises of the S.A.N.Z. There was only one change in membership on this committee during the year and C. H. McKeich is now the chairman.

Various matters relating to standards were considered during the year and are listed as follows:

Recommended to the Electrical Sectional Committee for adoption

BS 3871:1965 Pt. 1: Miniature circuit-breakers (with minor amendments) to supersede NZSS 1279:1958. Also recommended that the existing number (i.e. NZSS 1279) of the specification be retained in view of its wide use in the Electrical Wiring Regulations 1961.

D8626/1: Draft specification for bell transformers.

D8628/1: Draft specification for battery-operated electric-fence controllers.

NZSS 2041:1965 PD 5726, Amendment No. 1 to BS 3779:1964: Glass-fibre woven tapes for electrical purposes.

NZSS 1989:1965: PD 5743 Amendment No. 2 to BS 196:1961: Plugs, socket-outlets, cable-couplers and appliance couplers with earthing contacts.

NZSS 2065:1966 PD 5741 Amendment No. 1 to BS 3676:1963: Switches for domestic and similar purposes.

D8042/1: Draft specification for ceiling roses made of synthetic resin mouldings for use on 250 V circuits.

D8236/1: Draft specification for electric signs.

Draft specifications circulated for comment:

D8593: Temperature limits for the insulation and sheaths of electric cables at terminations.

D8604: Flexible cords insulated with glass fibre (limited circulation).

P838: Preliminary proposals for a standard on transformers for use with electrically-operated toys.

Standard Test Fingers

Consideration was given to PD 5744, Amendment No. 2 to BS 3042:1958 for a standard test finger for checking protection against electric shock. In this new standard the British made reference to four types of test fingers which are used for testing mechanical and electrical hazards. Only one of the four types is cited in the present New Zealand standard specification. Some difficulties will arise when the new British Standard for test fingers is cited if the New Zealand standard does not include all four types.

Enquiries have been sent to the Australian Standards Association about their policy in adopting their amendment to BS 3042:1958.

A report is requested from the Industrial Development Department of the University of Canterbury on the proposal to adopt the above British amendment.

A sub-committee was formed to draft a standard specification for "non-metallic conduit".

T. K. H. LEONG

ELECTRIC WIRES AND CABLES COMMITTEE

A meeting of this committee was held on 18 October 1966, when the following matters received attention:

(i) It was decided that at this stage there was no need for a specification for p.v.c.-covered conductors for voltages above 660 V.

(ii) It was decided to offer the co-operation of Standards Association to the Electric Supply Authority Engineers' Institute in the preparation of a standard specification for bare and p.v.c.-covered aluminium conductors for overhead power lines, and that a panel be set up consisting of representatives of manufacturers, supply authorities and the N.Z. Electricity Department ,to consider this.

As the four manufacturers' representatives on the Electric Wires and Cables Committee were all to be on this panel, your representative requested that an additional supply authority representative be appointed to the panel as any such specification was extremely important to supply authorities. This was agreed, and R. W. Hubbard was subsequently appointed. No meetings of this panel have yet been held.

(iii) A panel was set up to specify requirements for a non-sheathed single-conductor flexible cord for the wiring of appliances.

(iv) The draft standard specification for bare hard-drawn copper conductors for overhead power lines was recommended to the Electrical Sectional Committee for adoption.

(v) A draft amendment to NZSS 1908, covering p.v.c.-insulated cables for direct burial and light-duty p.v.c.-insulated flexible cords, was recommended for adoption.

W. G. JOHNSTONE

ELECTRIC HOT-WATER SYSTEMS COMMITTEE

No meetings were held during the year, and there does not appear to be any immediate requirement for meetings in the future.

J. H. VERNON

ILLUMINATION SECTIONAL COMMITTEE

No meetings have been held during the year, although the separate Building Illumination Committee has been active.

W. G. JOHNSTONE

STREET ILLUMINATION COMMITTEE

This committee had no meetings this year. The code of practice for lighting in streets other than main roads has been published and in the meantime this completes the committee's business.

J. D. ELLIS

HARDWOODS COMMITTEE

The committee completed the final draft for the new NZSS 168: Desapped hardwood poles, and this was to be circulated for comment in the usual way. Because of the need to get overseas comments three to four months have to be allowed, so no further action on this specification is likely until towards the end of this year.

At its most recent meeting the committee completed the final draft of all those portions of NZSS 485: Hardwood timbers which concern supply authorities and the final draft of this specification was also to be circulated for comment.

The practice, which is increasing in Australia, of using treated timber, particularly for poles, allows the use of naturally non-durable timber, obviates desapping, and allows the use of trees with smaller heart-wood measurements. On the other hand, the treatment is rather expensive, necessitating a pressure of several hundred pounds per square inch. The committee is awaiting recommendations from the Timber Development Association concerning the possibility of treating such timbers in New Zealand.

A. BUCKINGHAM

DOMESTIC REFRIGERATION COMMITTEE

No meetings were held during the year. The amended draft specification D8040/2 was declared NZSS 2167:1967 by the Standards Council on 26 April. The title is "Domestic electric refrigerators and food freezers" and the specification is now in the hands of the printers.

R. L. WILLIAMS

RADIO INDUSTRY SECTIONAL COMMITTEE

No meetings of this committee were held during the year.

J. E. COGHLAN

WELDING COMMITTEE

No meetings were held during the year.

M. G. KEYS

Reports of Committees

ALUMINIUM REQUIREMENTS

WHEN the investigation on the rationalisation of aluminium conductors commenced, supply authorities in New Zealand were using some 34 different sizes of conductor. This involved the use of a considerable variety of taps, joints, deadends, armour rods and tools. A standard list has been prepared which seems to have met with general acceptance except for a conductor between 0.06 and 0.1. This suggestion is being incorporated in a new standard conductor sheet about to be circulated.

It is difficult to prove that standardisation of aluminium conductors has resulted in economy in production of the conductor itself, but there are many fringe benefits associated with this standardisation that are worth noting.

(1) There is now an all-aluminium and an a.c.s.r. conductor available of the same mechanical size.

(2) Ten sets of fittings will accommodate the whole range of conductors.

(3) Manufacturers will need fewer aluminium and steel strandings.

(4) Manufacturers will be able to aggregate orders of similar conductors and improve delivery times.

(5) Interchange between supply authorities in times of temporary shortage of conductors, fittings, or tools, will be facilitated.

(6) More stocks of odd sizes of aluminium conductor will be reduced.

The right of any supply authority to choose a conductor not mentioned in the Institute schedule is not abrogated in any way. However, the range of conductors available in the standards list should prove adequate.

R. W. HUBBARD

DAIRY WATER-HEATERS

Matters were dealt with by correspondence and one meeting was held at Takapuna on the occasion of a regional meeting.

The main work this year was in revision of the Institute "Specification for Dairy Water-heaters" and the draft is complete. The revision was necessitated because of the development of cylinders in excess of 45 gal draw-off capacity. Larger quantities of hot water are being stipulated by the Dairy Division of the Department of Agriculture in newer types of dairy sheds where large herds of cows are milked.

The new specification is ready for submission to the Electrical Supply Authorities Association and is ready for printing.

Another aspect of the committee's work has concerned compliance with the old specification by two manufacturers.

O. C. STEPHENS (convener), J. W. ROGERS, J. D. SNELL, J. H. VERNON, C. L. WALTER.

EARTHING OF RURAL CONSUMERS' INSTALLATIONS

The increasing use in dairy sheds of milk-chilling vats with sealed-unit refrigeration pump and motor has rendered it impractical in such cases to isolate the consumer's neutral with its small but troublesome voltages from the vat. When an unbroken stream of milk is flowing into the vat the milk line is therefore also connected via this stream. This effectively prevents the common practice of isolating the milk line from the neutral conductor, and may reliven installations which had previously been freed from this trouble.

The cure then usually lies in the measures set out in D. S. M. Phillips' paper on "Small voltages on milking plants, their detection and elimination", and a number of supply authorities sent copies of this paper as a circular to their dairy consumers.

W. M. E. MIRAMS

ENGINEERING HISTORIES

Although no histories were completed and submitted during the year ended 31 July 1967, several were promised and the committee intends to have those promises fulfilled.

L. B. HUTTON (convener), J. K. HOOKER.

INJECTION FREQUENCY CONTROL

NORTH ISLAND

There was little activity during the year. Wanganui-Rangitikei E.P.B. advised that it had abandoned a scheme of integrating plants of different manufacture because of import difficulties, and would proceed to extend existing equipment by the installation of a further 5 kW injection plant in July 1968, and conversion of an existing 400 V injection to 11 kV. Egmont E.P.B. sought opinion on the merits of two frequency proposals likely to be involved in reorganisation of its ripple control system, necessitated by change to 33 kV subtransmission, and this has been given by members direct to that authority.

During the year a serious fire originated from the failure of plant, and plant operatives are urged to check the layout of their plants to protect against similar possibilities.

Some correspondence was conducted among the supply authority committee members concerning the implications of plant and relay manufacture in New Zealand by one manufacturer. It was felt that such could lead to the exclusion of importation of other manufacturers' equipment and that this would lead to unnecessary complications.

R. P. Stevens has replaced D. W. Harris on the committee as the result of the latter's move to the South Island.

P. A. GRIFFIN (convener), A. R. DAVIS, J. D. ELLIS, F. FOSTER, H. R. GUNN (N.Z.E.D.), N. J. HARTLEY, R. P. STEVENS.

SOUTH ISLAND

This committee did not meet during the year; it had little reason to exchange correspondence and it has nothing to report.

S. R. ANSTICE (convener), D. J. BINNS, J. E. COGHLAN, H. R. GUNN (N.Z.E.D), E. A. JEFFS, J. P. SHELLEY.

LIGHTNING

No matters were referred to this committee during the year.

M. D. MACPHEE

LINEMAN'S HANDBOOK

The work of this committee has been completed and the revised edition is now in the printer's hands.

Unfortunately progress is held up pending approval of the revised safety rules which are reprinted in the "Lineman's Handbook" from the "Safety Manual".

C. M. GRAY (convener), W. G. JOHNSTONE, A. M. SPENCER.

POWER SUPPLY

General

The committee did not have reason to meet during the year. Some information was provided at short notice for the president of the Electrical Supply Authorities Association relative to progress with Marsden Point, Tokaanu and Manapouri power projects.

The Power Planning Committee's 1967 report is the first for some time to recommend such a relatively small change from the programme introduced in the previous year. This reflects a slight easing in the rate of growth in demand for electricity, and the present trend towards thermal plant with its firm energy rating and its relatively short and easily predicted design and construction times.

Load factor

The continuing deterioration in system

load factor is considered to be one of the most serious trends evident in the pattern of consumer demands for electricity. It is the opinion of the committee that the use of natural gas and the current financial difficulties will accelerate the rate of change in load factor and that the implications of this trend warrant detailed investigation.

The committee have been made aware of the measures introduced by certain authorities in their more recent tariff reviews, to encourage consumers to improve their load factors, and of the success experienced with them. Power planning which fails to emphasise the need for proper shaping of consumer demand through realistic retail tariffs ignores the fact that only intelligent marketing can offset the current pressures which threaten the industry's economic position.

Hydro-electric development

The Power Planning Committee's recommendation that the height of Lake Pukaki should be raised is to be supported as the inability of the present storage capacity to make better use of the run-off in this area leads to the loss of a significant proportion of its energy potential.

Geothermal development

The 1967 Power Planning Report indicates that there are grounds for regarding future geothermal development in a more optimistic light although further investigation is necessary before a firm decision can be made.

Nuclear generation

It is now apparent that a good deal of consideration is being given to forward planning in the area of nuclear generation. As the General Manager of the N.Z. Electricity Department points out, the present tentative programme will not be an easy one to meet and the actual year in which the first nuclear-fuelled generation will take place cannot as yet be accepted with certainty.

It is of interest to note that in terms of the present estimates of cost it would appear that, on the basis of useful energy delivered to the consumer, the overseas content in electricity generated in nuclear power stations will be about half of that in natural gas imported in a liquefied form which has been proposed as a likely source of supply to the gas industry when Kapuni is exhausted. This comparison gives no credit for the enrichment process which will take place in the nuclear plants proposed for New Zealand but it allows for the overseas content in the power station as well as the fuel. At the same time the gas costs are not debited with any overseas expenditure on the shore terminal necessary for the importation of liquefied natural gas.

S. R. ANSTICE (convener), D. J. BINNS, T. E. KELLY, M. G. KEYS, J. P. SHELLEY, C. L. WALTER.

PUBLICATIONS

This report covers contributions to the *N.Z. Electrical Journal* by Institute representatives of member authorities during the year August 1966 to July 1967.

August 1966

1966 conference papers of institute

"Hot stick working"—N. R. White

"Northern regional meeting"—K.G.S.

September 1966

"Kuriwhao Peak"—R. P. Thomson.

"Portable injection frequency fire alarm call-out system"—R. C. Douglas.

Conference reports of committees and representatives.

October 1966

No contributions.

November 1966

No contributions.

December 1966

Northern regional meeting—K.G.S.

January 1967

"Tauranga E.P.B. safety poster competition"—N.R.W.

February 1967

"Heaters for udder washing"—A. R. Davis.

"Injection-frequency problem and its solution"—R.C.H.

Correspondence—"The uneconomic use of engineers"—S. R. Anstice.

"Central linemen's contest"—C.H.V.W.

March 1967

"Cable trenching in the jet age"—S. J. Winfield.

April 1967

"A graphical method of determining relay settings"—I. G. Webster.

"Central region linemen's competition"—C.H.V.W.

"Northern regional meeting"—K.G.S.

May 1967

"Opening of major Wellington substation"—J.K.H.

June 1967

"The inauguration of Wairoa M.E.D. Engineering Department"—G. K. McKenzie.

July 1967

"Economic considerations of distribution power system planning"—B. P. McRae.

1967 conference papers.

The Publications Committee expresses its thanks to those who have contributed to the *Journal* throughout the year, but it must comment that it is disappointed with the very small response by supply authority engineers to persistent requests for contributions. Only 13 persons contributed during the past 12 months and of the 17 items published over half were notes rather than articles. Eight technical articles were published during the year, compared with 19 the year before and 34 the year before that.

The committee must again emphasise that the *N.Z. Electrical Journal* is the medium for engineers to convey matters of interest to their fellows and we again solicit their support.

The gazetting of the Electrical Supply Regulations 1967 has resulted in the publication of ten codes of practice which are a valuable addition to our technical libraries, while the "Lineman's Handbook" and "Safety Manual" have been revised and rewritten, and are now awaiting final approval from other bodies before being published.

T. E. KELLY (convener), S. R. ANSTICE, M. G. KEYS.

RADIO AND TELEVISION

In our last report reference was made to a recommendation received from the Engineer-in-Chief, Post Office, in regard to a re-allocation of medium frequencies to overcome mutual interference experienced by several supply authorities.

Tests have now been carried out by these authorities to see whether the proposals of the Post Office will overcome their difficulties and the following is the present position:

*Hamilton C.C. has intimated that it does not wish to proceed with a change to a frequency of 1705 kc/s.

*Te Awamutu E.P.B. has replied that it does not wish to change from medium frequency to a v.h.f. allocation and is finding the present frequency at 1705 kc/s to be quite satisfactory.

*Tauranga E.P.B. has investigated the possibility of a complete change to v.h.f. allocation.

*Waitemata E.P.B. has carried out tests on 1605 kc/s to see whether interference would be experienced from Hawke's Bay E.P.B. and Taumarunui B.C. and reports that both tests were satisfactory.

It is important that users of medium frequencies realise that any difficulties they are having with congestion on their radio channels will deteriorate with the passage of time and as they increase their occupancy of the channels already allocated. The Post Office is most unlikely to approve the allocation of any additional medium-frequency channels.

In last year's report of the committee the recommendation was made to member authorities to evaluate the possibility of using very high frequencies. Because of the fact that v.h.f. can be allocated on the same frequency over and over again, as long as the areas are separated by

physical barriers such as hills, being line-of-sight communication, there is unlikely to be a shortage of v.h.f. channels for many years to come.

Unless the terrain of a particular member authority is, by virtue of its undulating nature, unsuitable for v.h.f. communication there are many benefits to be derived from a change to v.h.f. of which the following are the most important:

(1) Lack of congestion because of the greater frequency spectrum available.

(2) Lack of interference from distant stations such as Chicago, Sydney, and San Francicsco through reflection of signals from the ionosphere.

(3) The elimination of costly antenna replacements experienced with medium frequencies as a result of the very much shorter antennae used with v.h.f.

(4) Very high frequency operates on much lower power with consequent lower battery drain.

(5) The smaller physical size of v.h.f. components results in much reduced size of equipment.

(6) Freedom from static interference on base stations.

Note.—With medium-frequency transmission it is common for a very strong interfering hiss to be experienced when rain storms pass base station antennae. This has been known to make communication impossible. This effect is absent with v.h.f.

At the time of writing this report a reply is awaited from the Engineer-in-Chief of the Post Office to a request that a meeting be arranged between himself and the convener of this committee to discuss:

(i) The results of supply authority evaluation of suggested medium-frequency allocations.

(2) Post Office policy in regard to v.h.f. allocation and in particular the question of ownership of base stations.

(3) The effect that the introduction of single side-band transmission will have on frequency allocations to supply authorities.

In some areas the Post Office is not able to cover the area of supply of an authority requesting a v.h.f. service and the establishment of base stations is then left to the authority concerned.

As the Post Office is also the radio frequency licensing authority it is likely that the Post Office will expect to provide base station facilities where these are or can be made available.

Where a satisfactory Post Office service is available it is important to know just what the Post Office fee for the service embraces. The present Post Office licence fee of £575 per year provides for a single exclusive-use channel and it is understood that this fee includes base-station line control facilities including the licence fee for as many mobiles that the supply authority desires to add. This means that there is a limit to the number of mobile stations above which it is uneconomic for an authority to operate its own system.

Only in cases where few mobiles are used, or where suitable base stations can be located in easily accessible places, is it likely that a supply authority can establish its own base-station facilities at an annual cost lower than the Post Office fee.

Any authority contemplating a change to v.h.f. should seek the following assurances from the Post Office before accepting service:

(1) An assurance that emergency generating plant is installed at the base station.

(2) An assurance that an emergency channel is available for temporary use in the event of failure of Post Office base station channel equipment.

Note.—The second provision is of importance because of the fact that Post Office maintenance staff often have to travel a considerable distance to base stations after a fault is notified and interruptions can occur of up to two hours in some places before attention to a fault.

At the annual conference the committee expects to be in a position to report further on meeting with Post Office engineers.

N. R. WHITE (convener), J. C. BUCKINGHAM, J. B. NICHOLLS, J. H. VERNON, R. L. WILLIAMS.

SAFETY PROCEDURES — ISOLATION AND RESTORATION OF SUPPLY

This committee has never met since it was formed in 1962, although a report produced from correspondence was presented to the 1963 conference.

The new supply regulations have now been issued and it is the opinion of the committee that no useful purpose can be served by continuing this committee and it is therefore recommended that it be abandoned.

T. H. WATSON (convener), D. J. BINNS, D. T. A. BULLICK, R. W. HUBBARD, E. H. MACE.

SAFETY RULES

The committee has produced a final draft of the Safety Rules which are now in proof form and have been submitted to the N.Z. Electricity Department and to union representatives. Final approval from these bodies has not yet been received.

J. P. SHELLEY (convener), D. T. A. BULLICK, B. J. HARRIS, E. D. HOUNSELL, D. R. LORD.

SINGLE-PHASE EARTH-RETURN SYSTEMS

The material relating to the proposed review of the 1962 Australian conditions for single-wire lines is still being considered by the committee. It is understood that the review of the Australian conditions has not yet been completed.

The committee is disturbed to find that the Electrical Supply Regulations 1967 appear to require 22 ft ground clearance for lines operating at a voltage of 11 kV above earth in contrast to the 18 ft required in the 1935 regulations. As far as is known there has not been a chapter of accidents with these lines—which are invariably built across sparsely settled country—to suggest that the greater clearance is required. A case is being prepared to support 18 ft above ground being the required clearance.

J. D. HAIGH (convener), H. L. HOY, L. MANDENO, N. SANDERS, K. G. STEWART, R. P. THOMSON, N. R. WHITE, K. A. WIILSON.

STATISTICS

No meetings of the committee have been held during the year.

The 1966 report of the combined committee to the Electrical Supply Authorities Association gave a detailed guide to the counting and classifying of consumers which was drawn up in consultation with officers of the N.Z. Electricity Department. Members are reminded that it is the intention of the Department to implement the new classifications for the annual return (NZED 705) for the year ending 31 March 1969.

H. A. JENKINS

STATUTORY VOLTAGES

Committee activity during the last 12 months has been confined to obtaining information on several points raised by the N.Z. Electricity Department.

The Department is awaiting a reply on the following:

(a) The effect of the increase of voltage on existing appliances.

(b) Rating of plug-socket outlets.

(c) Increased load on system.

(d) How the increase in voltage could be carried out.

Further discussions took place with the Department in March on the information received relating to the above points.

D. W. HARRIS (convener), A. BUCKINGHAM, P. A. GRIFFIN, M. D. MACPHEE, R. H. O'CALLAHAN, H. A. L. WILY.

SUPPLY REGULATIONS CODES OF PRACTICE STEERING

Many years ago the Institute undertook to issue codes of practice on various aspects of electrical distribution work at the time of the issue of the revised Electrical Supply Regulations.

Nine codes were prepared and approved by the Executive Committee some 10 years ago. They were then submitted to the General Manager, N.Z. Electricity Department and were supplied to members of the Electrical Supply Regulations Revision Committee.

This year the Steering Committee ensured that references to supply regulations and other publications mentioned in the codes were correct and made only a few minor changes in the light of later information and the 1967 regulations.

The following codes have been published since the gazetting of the Electrical Supply Regulations 1967.

Earthing requirements;
Feeder and distribution protection;
Low-voltage underground cable;
Overhead conductors of primary distribution lines;
Overhead secondary distribution lines;
Supports for overhead primary distribution lines;
Switchgear; and
Transformer structures and cubicles.

A code for cable installations and a new code for Post Office requirements are about to be published.

Sag tension charts prepared by the engineering staff of the Hawke's Bay E.P.B. and the Central Waikato E.P.B. were also published this year.

The committee has been asked by the Executive Committee to undertake a major revision of the codes. The president of the Electrical Supply Authorities Association has asked for more standardisation of materials and methods and the codes can be used as basis.

J. D. ELLIS (convener), D. J. BINNS, R. W. HUBBARD, T. E. KELLY, M. D. MACPHEE.

Post Office requirements

This committee was set up by the Executive Committee to produce a code of practice co-relating Post Office requirements with the Electrical Supply Regulations 1967. Included in the committee was a representative of the Post Office.

It was emphasised that the code should be produced as quickly as practical as it was intended to print it along with other codes of practice which had been completed for some years. Work commenced in January and following correspondence a meeting to finalise the basis of the code was held in April. The final code was approved for printing in July.

An endeavour has been made in the code to include common methods of construction which are not detailed in the Electrical Supply Regulations, but which have the approval of the Post Office.

Some difficulty was experienced in determining an easily understandable and generally satisfactory method of protecting Post Office wires on power poles carrying air-break-switch operating wires or handles. The suggested solution aims at removing any dangerous voltage gradients that may occur on the operating equipment where it passes the Post Office wires. The use of plastic sleeves on the operating rods was not considered satisfactory as insufficient data are available on their protective qualities after some years of exposure.

Approved clearances between underground cables are also dealt with and should be of considerable value in view of the increasing use of underground reticulation.

M. D. MACPHEE (convener), D. J. BINNS, R. M. O'CALLAHAN, R. H. WILSON (Post Office).

TRAINING FORUMS

On the basis of the very successful management seminar held at Victoria University of Wellington in October 1965, arrangements were made for a further seminar. Owing to the World Power Conference in Tokyo in October 1966, a circular was sent out to ascertain the most suitable date for this second training forum.

The results showed that of the three periods suggested, the one suitable to the greatest number of supply authorities was May 1967. In consequence the Institute's second management function was arranged to take place at Victoria University of Wellington during 16-18 May 1967.

When a call was made for applicants to attend the seminar, many of the authorities who had indicated that they would have one of their officers attending, did not, in fact, take up their option. The attendance was therefore somewhat lower than the 32 expected. The seminar did, however, take place as arranged.

The seminar director was once again Derek Tayler, B.Com., F.R.A.N.Z, A.I.A.N.Z., F.N.Z.I.M., senior lecturer, Department of Accountancy, Victoria University of Wellington.

For the first seminar complete local arrangements were made including accommodation and transport, and these worked out admirably. N. Ashley, of Wellington M.E.D. acted as course secretary.

As a result of the experience in the first seminar, some alterations were made in the pattern of subjects and speakers, and there was no doubt about its success. The subjects covered and the speakers were:

Introduction—D. Tayler, Victoria University.

"Principles underlying good management"—J. F. Robertson, assistant commissioner, State Services Commission. (Delivered by D. Tayler).

"Local body politics"—Prof. R. H. Brookes, Victoria University.

"Financial reporting"—Prof. R. Sidebotham, Victoria University.

"The practice of management"—Prof. E. A. B. Phillips, Victoria University.

"The role of New Zealand trade unions"—A. J. Neary, North Island Electrical Workers' Union.

"Adaptation to change"—J. V. T. Baker, Government Statistician.

"Management and people"—A. Marshall, senior lecturer in Business Administration, Victoria University.

"Communicating yourself to others"—F. N. Stace, secretary, Electric Supply Authority Engineers' Institute.

"Critical path analysis"—R. G. Norman, assistant commissioner, State Services Commission.

"A case study"—N. P. Angus, assistant commissioner, State Services Commission.

Closing address—J. H. Ingram, Cable Price Corporation.

Addendum

The course director reports that of the 28 attending the seminar, 26 sent in replies to his questionnaire. Most of the replies favoured the present length of the course and its being held annually.

There were two suggestions that should be considered:

(1) That a review or follow-up course of say one or 1½ days be held some six to eight months after the seminar.

(2) That supply authority secretaries and accountants be invited to participate.

Referring to (1), it is considered that it would be better to have further 3-day courses specifically for those officers who have previously attended training courses. These courses could be partly follow-up and partly additional and more advanced.

With (2), the points of consideration are:

(a) Is the information given such that it is required by both professions?

(b) Would there be administrative advantages and broadened discussion if both engineering and financial persons were participating?

There is no doubt that at management level the problems are the same whoever

is dealing with them. It could be, however, that the assistance required by a man basically an engineer would differ from that required by a man basically an accountant.

J. K. HOOKER (convener), J. D. ELLIS, F. N. STACE.

UNIVERSITY TRAINING OF ELECTRICAL ENGINEERS

The committee has had no meeting so far. Further consideration has been given to the subject, however, subsequent to an address to engineers of the Northern Region by Dr A. G. Bogle.

A suggested syllabus has been received from the Auckland school of Engineering, and a short meeting was arranged with Professor L. Kay of the Canterbury School. It was thought desirable to await Dr Kay's address to the 1967 conference before proceeding with the committee's report.

S. E. SLATTER (convener), J. K. HOOKER, M. G. KEYS.

WATER-HEATER TESTING STATIONS

The following shows the work carried out by the various testing stations:

(a) *Auckland*

Type	*Gallons*	*Tested*	*Passed*	*Failed*
Domestic	30	4	–	4
Totals		4	–	4

(b) *Christchurch*

Type	*Gallons*	*Tested*	*Passed*	*Failed*
Domestic	40	1	–	1
Totals		1	–	1

(c) *Wellington*

Type	*Gallons*	*Tested*	*Passed*	*Failed*
Dairy	60	1	1*	–
Totals		1	1*	–

Note.—*Cylinder had a mean loss of 4.80 kWh. Although no maximum heat loss is specified for this size of dairy cylinder (which is beyond the present scope of the Institute specification) the draft of the revised specification provides for a heat loss of 5.2 kWh.

J. K. HOOKER (convener), B. M. COLE-BAKER, J. P. SHELLEY.

WELDING

No matters were referred to the committee during the year and it has nothing to report.

M. G. KEYS (convener), W. M. E. MIRAMS, L. E. RASMUSSEN, I. R. ROBINSON, J. P. SHELLEY.

Discussion on reports

ELECTRICAL REGULATIONS ADVISORY COMMITTEE

The secretary read the following letter from the General Manager, N.Z. Electricity Department:

Electrical Regulations Advisory Committee

The above committee, originally established in 1925 for the purpose of advising on matters pertaining to the Electrical Supply Regulations and the Electrical Wiring Regulations has not been called together since October 1958. The committee last functioned (on a postal basis) in February 1961.

The advent of the Electrical Wiring Regulations 1961, which includes provision for the setting up of the Electrical Wiring Regulations Committee, limited the functions of the Electrical Regulations Advisory Committee to matters that could arise under the Electrical Supply Regulations 1935. The committee has not been required to consider any such matter for several years past; in fact, since February 1961.

The changed character of the Electrical Supply Regulations 1967, which came into force on 1 April 1967, makes it unlikely that there will be many matters arising that cannot be dealt with by the Department. If such a matter did arise it would be relatively simple to arrange for a meeting of representatives of the organisations concerned for the specific purpose of considering the matter. A continuing committee is therefore considered unnecessary.

In view of the foregoing the Minister of Electricity has approved the disbanding of the Electrical Regulations Advisory Committee.

May I take this opportunity of expressing to you my thanks for the services the representatives of your organisation on the committee rendered to this Department and the electrical industry generally over the many years that the committee was active.

The secretary said some would recall that 30 to 40 years ago the entire work of the annual conference revolved round the work of the Electrical Regulations Advisory Committee. That committee had drawn up both wiring and supply regulations, had issued interpretations to them and had revised them, and virtually the whole of the conference business in the 1930s had been discussion on regulations.

The committee, on which the Institute normally had two representatives, had been in existence for 41 years, but over that period only eight Institute members had been involved. During recent years there had been very few meetings of the committee, but over the years there had been a total of 452 meetings, 443 of which were held during the 25-year period 1925-49. Institute representatives on the Electrical Advisory Regulations Committee had been:

1925-36 G. Lauchlan, 280 meetings.
1925-39 J. G. Lancaster, 321 meetings.
1936-43 J. A. Smith, 96 meetings.
1940-55 R. S. Maunder, 125 meetings.
1944-47 J. B. Grey, 40 meetings.
1947-55 F. O. Devlin, 31 meetings.
1956-67 A. Mill and T. E. Kelly, 5 meetings.

The president said everyone was indebted to those people for the amount of work they had put in, both at home and at meetings over those years.

ELECTRICAL WIRING REGULATIONS COMMITTEE

M. D. MACPHEE: The report of the Executive Committee mentions caravan warrants, and says that supply authorities should see that the requirements are enforced. The General Manager, N.Z. Electricity Department, had been asked to advise camping ground owners accordingly.

Does our representative consider the present period of 12 months before the caravans have to be reinspected reasonable? I have travelled round the country recently in caravans, and those that I hired have never had a current warrant of fitness and I was never asked for one in a camping ground.

With modern wiring, it appears unlikely that a fault will occur within 12 months from the last inspection. A period of three to five years between inspections would be more practical and there might then be a better response. In one caravan that I hired the date on the warrant had been changed regularly over a period of about five years.

Is there any regulation that compels the owner of a camping ground to look at the warrant?

A. MILL: I know that the Department sent a circular to camping ground owners. I know also that in some cases the requirements are enforced strictly, to the embarrassment of some supply authorities because their inspectors are called out at night or in the weekends to supply warrants, and they are not happy about this because they do not know the histories of the caravans.

The problem is: do you take a risk and extend the period, or do you see you have a good safe system that is working? It is of interest to note that in the 14th edition of the I.E.E. regulations, where they have introduced caravan requirements for the first time, they

have followed our example and have asked for an inspection in 12 months.

One of the difficulties is that this depends on the individual camp owner, but it is a legal requirement.

Mr Macphee should write to the Department and it could be followed up to see whether there was evidence to justify any change.

ELECTRICIANS REGISTRATION BOARD

THE PRESIDENT: The Executive Committee has been asked to comment on proposed amendments to the Electricians Act 1952. The amendments provide for the following classes of registration—considerably minimising the number existing at present:

(1) Inspectors, as at present.

(2) Supervising electricians, being holders of an Advanced Trade Certificate and with experience similar to that prescribed for inspectors.

(3) Electricians, as at present.

(4) Radio servicemen, with qualifications as at present and authorised to undertake the servicing of electrical and radio apparatus.

(5) Electrical servicemen, a new classification to apply to a consolidation of the present limited registration classes.

(6) Assistant electricians, assistant radio servicemen, and assistant electrical servicemen. This group includes the existing electrical servicemen who would be reclassified as assistant electricians. Otherwise the group is comprised of those who have had the necessary experience for the appropriate registration but who have failed to complete all the examination requirements.

The Executive Committee felt that the category of assistant electricians should embrace people who are attending part-time study in electrical work. Otherwise the executive generally endorsed the proposals in principle.

ALUMINIUM REQUIREMENTS COMMITTEE

R. W. HUBBARD: In the report I mentioned that there is a suggestion that we incorporate a conductor between 0.06 and 0.1 in^2. This has now been done and the amended list circulated to all member authorities.

There have been suggestions that the range of conductors is a little limited. I would point out, however, that there are some 12 all-aluminium and 12 a.c.s.r. conductors available as standard conductors, but it in no way limits the choice of conductor to any particular supply authority. It is interesting to record that although engineers generally are prepared to work with a small range of copper conductors, when aluminium is chosen in New Zealand no less than 34 different sizes are wanted. The rationalisation of conductor sizes was not to limit the choice of the engineer but to bring a little sanity to that choice so that fewer would be required, and not so much material would require to be imported from overseas.

H. R. MATTHEWS: When paper cables are manufactured in New Zealand, are these sizes intended to be used for paper-insulated cables, or will a new standard of aluminium conductors have to be introduced for that purpose?

R. W. HUBBARD: The matter has not been discussed with manufacturers, but the interesting thing that emerges from the types of cables that are ordered is that, generally speaking, supply authorities can get by with four or five sizes of paper-insulated cables, but when it comes to overhead conductors a great range is required. I foresee no difficulties with paper-insulated cables. The armoured cables fall into narrow confines and it would be the same with paper-insulated cables.

W. G. JOHNSTONE: Mr Hubbard remarked that people limit themselves to a very small range of sizes of copper overhead conductors and the same might arise with aluminium. There is still some concern that, although we have a standard for p.v.c.-covered copper conductors, people are not keeping to it, and a number are working outside that range. If we cannot do that for copper it is going to be even more difficult to persuade users to keep to this range for aluminium cables. Most authorities could surely do more than they are in this.

ENGINEERING HISTORIES COMMITTEE

J. K. HOOKER: Some will recollect that L. B. Hutton used to appeal for histories. Recently I was given that job, and some 30 requests have been sent out. Members should be proud of their supply authorities, and will get much satisfaction from delving into history and recording it.

PUBLICATIONS COMMITTEE

T. E. KELLY: Each year I make a plea to members to provide articles for the *N.Z. Electrical Journal*. I am now making a demand.

Last year we had half the number of articles provided for the year before, that which in turn had only half the quantity provided for the year before it. We agreed to support the *Journal* by the provision of articles, so please write. It is one way of getting well known.

M. G. KEYS: Members of the Northern Region will be getting a letter from me telling them when they are due to provide an article. They will get a following letter, then another one, and after that we will disconnect them!

THE PRESIDENT: We must all have had something of interest at some time, be it only a picture with a caption underneath.

RADIO AND TELEVISION COMMITTEE

N. R. WHITE: There are some additions to the report arising from correspondence between the committee and the Post Office since the report was prepared. The plea is made in the report for those member authorities who can use v.h.f. to do so, with the hope that users who must use medium frequencies because of the terrain of the area of their supply can have more space to occupy. I have been in the rather strange situation of wearing two hats in this connection, as my board is currently negotiating for a v.h.f. with the Post Office, not entirely satisfactorily.

I had hoped that I would have had a letter from the Post Office in time for this conference.

I believe that the Post Office service is a good one. It suffers, however, from a few limitations, and member authorities should make sure that when they negotiate with the Post Office, they endeavour to have all their conditions incorporated.

W. H. HICKSON: An answer to Mr White's letter of inquiry to the Engineer-in-Chief will be in Mr White's hands shortly. The Post Office is very sensitive of the needs in an emergency of power supply authorities, and every step will be taken to try and reach a suitable compromise on the conditions which Mr White is seeking.

W. LANGBEIN: We experience interference from ships' Morse code. I understand that there are complications in that nobody has control over overseas ships in New Zealand waters, but something might be done about it.

N. R. WHITE: This has been discussed with the Post Office but very little can be done. Very much of this is on medium frequencies and the signals come from far away. Because a medium frequency is being used the ionosphere reflects the signals back. For instance, many supply authorities have interference from San Francisco. Nothing our Post Office could

do can alleviate this. This strengthens my point in urging supply authorities to get on to v.h.f. if they can.

TRAINING FORUMS COMMITTEE

J. K. HOOKER: In the addendum to the report there is a suggestion that supply authority secretaries and accountants be invited to participate in our seminars which are for management—not just engineering, or accounting, or secretarial work.

THE PRESIDENT: The Executive Committee have agreed that further management seminars should be combined ones for both engineers and secretaries.

N. R. WHITE: I enjoyed attending one of these seminars, and received a lot of value from it. I had not thought about secretaries attending, but I did feel that some of the papers would have been useful for elected members. Possibly some of the addresses could be published in the *N.Z. Electrical Journal*, for instance the paper on local body politics by Professor Brookes was a fine contribution.

THE PRESIDENT: We will keep that suggestion in mind.

UNIVERSITY TRAINING OF ELECTRICAL ENGINEERS COMMITTEE

R. W. HUBBARD: Recently in Auckland the N.Z. Institution of Engineers ran a symposium on engineering education. One of the subjects discussed was the education of the intermediate group, the technical assistant or the engineering cadet who starts with a supply authority with the idea of qualifying for the Certificate of Engineering. Then if he is really bright the supply authority might send him to University.

Has Mr Slatter had any discussions with the University of Canterbury on this aspect of permitting Certificate of Engineering students to go through to University to take a B.E. degree? There is an apparent reluctance on the part of the University of Auckland to do this.

S. B. SLATTER: That aspect was not specifically discussed with Professor Kay and it was not a specific topic of discussion with Dr Bogle when he addressed the Northern Regional meeting. The subject is well worth pursuing and I suggest it be brought up after Professor Kay's address.

SAFETY RULES COMMITTEE

N. R. WHITE: A committee has been drawing up a code of practice. Is Mr Ellis in a position to present a verbal report?

J. D. ELLIS: A draft code of practice for live-line hot-stick working has been completed. It is only a draft and it has now been passed on to the electrical workers for comment. I understand there is to be a further meeting with them some time in November.

General Business

I. G. J. LE CREN mentioned that his Board had developed a two-channel injection-frequency relay and invited anyone interested to look at it.

I. A. MCCUTCHEON asked about the testing of rubber gloves which had been discussed at regional meetings. He read the appropriate supply regulation and referred to BSS 697. He said there were several questions to be resolved.

The president said the matter was before the Executive, information was being obtained, and would be promulgated to all members.

OFFICERS AND EXECUTIVE FOR 1967/68

The secretary announced the new officers and executive as follows:

President: S. R. Anstice (Dunedin C.C.).

First vice-president: M. G. Keys (Auckland E.P.B.).

Second vice-president: W. M. E. Mirams (Taranaki E.P.B.)

Immediate past president: C. L. Walter (Central Waikato E.P.B.).

Executive: The following six elected members:

D. J. Binns (Ashburton E.P.G.B.).
J. D. Ellis (Hutt Valley E.P.G.B.).
R. W. Hubbard (Waitemata E.P.B.)
J. P. Shelley (Christchurch M.E.D.).
S. E. Slatter (Central Canterbury E.P.B.).
O. C. Stephens (Thames Valley E.P.B.).

Several past presidents would remain *ex officio* members.

The president congratulated members elected and thanked all those who had allowed their names to go forward for ballot. He thanked the scrutineers, G. H. Battersby and R. D. Veitch.

A motion to destroy the ballot papers was carried.

APPOINTMENT OF AUDITORS

The president, seconded by G. H. Battersby, moved that the present auditors, Clark, Menzies & Co., be reappointed.

The motion was carried.

Report of Awards Committee

T. E. KELLY: In giving the report of the Awards Committee I would like to read the items which the conditions request the committee to take into account in considering the merits of a paper. In brief they are: (1) Its value to members, (2) The manner of its presentation, (3) The author's reply to discussion, (4) The originality, accuracy and general format of the paper.

During this conference the opinion of the Awards Committee have changed several times. We have had four papers of a very different nature to consider. All of these papers have been most ably presented, and all of value to this Institute, indeed papers which we will refer to on future occasions, and you will agree when I say that the decision of the Awards Committee could not possibly be decided until the last word was spoken by Mr White.

We finally felt that, if you consider the value of the paper to the members of the Institute, this morning's presentation by Mr White and the interest the members took in his paper was very real, and the manner in which Mr White replied to the discussion on some very awkward points raised was well worth while.

The Awards Committee therefore recommends that the Award this year should be made to N. R. White.

The president congratulated Mr White and thanked the authors of the other papers for their very worthwhile contributions.

DISCUSSION ON

The Electrical Supply Regulations 1967

THE PRESIDENT: At the executive meeting on 2 August recommendations concerning the Electrical Supply Regulations 1967 were received from both the Northern and Southern Regions. The Northern Region asked that all supply authorities be circulated in order to ascertain details of new supply regulations which were considered difficult to interpret or else ambiguous, while the Southern Region criticised no fewer than 10 of the new regulations.

In view of the regional views, the executive agreed that the business agenda for this conference should include a discussion on the Electrical Supply Regulations 1967, but that this discussion should be confined to specific regulations and that all members should be notified of them in advance.

Notification was accordingly given that various regulations will be discussed and I will now ask Mr Kelly as one of the members of the Electrical Supply Regulations Revision Committee to comment on the queries raised.

[For convenience extracts from the regulations concerned and the questions asked about them are quoted.—Ed.]

E.S.R. 15 (d): Two-wire system (whether direct current or single-phase alternating current) as a normal rated voltage of 230 volts: . . . and . . .

E.S.R. 17: *Voltage—(1)*: The voltage at the main switchboard on a consumer's premises shall be maintained within 5% above or below the standard voltage.

Question: As these regulations make it mandatory for an authority to supply at 230 V ± 5%, what is a supply authority's legal responsibility for damage resulting from greater variations?

T. E. KELLY: These regulations are practically the same as E.S.R. 21–01 and 21–21 of the 1935 regulations. It is admitted the regulations do not specifically say who should maintain the voltage, but we have the advantage now that 17 (2) does limit more precisely the responsibility of the supply authority. Although the regulation does not define responsibility (nor do the previous regulations) I am quite sure that if responsibility were ever tested in the courts it must be found to lie with the supply authority. These regulations are made with that in mind, and I do not think that you can evade them, nor do I think that they could be written in any other form.

E.S.R. 36: The electrical supply authority shall have power to refuse a supply of electricity to any new installation which does not at the time of inspection before the commencement of supply comply with these regulations and of the Electrical Wiring Regulations 1961 or in respect of which the requirements of the Electricians Act 1952 have not been complied with.

Question: This regulation does not cover extension and if supply is refused the consumer is penalised for a contractor's poor work.

T. E. KELLY: The regulation is very similar to the previous ones, which did not mention an extension, which is covered by Electric Wiring Regulation 12. There is no doubt that the consumer is penalised. You can do what you like to the contractor, but some one has to pay, and that must be the consumer. I cannot see any other method.

E.S.R. 45 (b): An electrical supply authority shall inspect and test . . . before the reconnection of supply where premises have been disconnected for longer than six months or disconnected for reasons other than non-payment of account, change of occupancy, or absence of occupant.

Question: This regulation does not allow for the pole fuse to be removed temporarily for painting, without an inspection and test of the consumer's installation.

T. E. KELLY: Provisions (b) and (c) [where the supply authority deems it advisable to carry out an inspection] were included to establish some basis for reinspection, but it never entered our minds that it should apply for a short disconnection such as for painting. It may be prudent to have an amendment to this regulation. The requirement is a necessary one, according to the strict reading of the regulations, but it may put a supply authority in an embarrassing position.

If the supply authority who posed this question cared to promote a change in the regulation, to allow for a temporary disconnection for a short period not requiring a reinspection, it would be favourably received.

E.S.R. 46: If as a result of any inspection or test, any defect is found in any portion of the fixed wiring on any consumer's premises or in any equipment or appliance permanently connected with any such fixed wiring, the electrical supply authority shall immediately notify the consumer in writing of the defect, and require him to have it remedied within a reasonable time to be stated in the notice.

Question: There is no provision for notifying the contractor.

T. E. KELLY: This refers specifically to E.S.R. 45, which is work to be done in the house or the property. I do not think that notification could be given to a contractor. It must be given to the consumer as at that time it would not be known who the contractor was. The regulation is correct.

E.S.R. 66: Fire buckets filled with clean dry sand and ready for immediate use in extinguishing fires, or suitable fire extinguishers filled with non-conduction extinguishing agents, shall be kept in all powerhouses and substation buildings, in a convenient situation adjacent to the electrical apparatus and shall be conspicuously marked.

Question: Conflict has arisen with the N.Z.E.D. interpretation of the words "adjacent to".

T. E. KELLY: "Adjacent to" has been a term used for many years, and it is just as correct as "effectively placed". This is a play on words. If anybody wants to amplify this, please do so.

C. H. MCKEICH (N.Z. Electricity Department): Since there is an allegation against the Department, I had a look at this beforehand. We are not aware of any conflict in the regulations. We believe the inclusion of the word "buildings" in the new regulation, which was not in the old regulation, has removed some difficulty experienced under the old regulation. Any conflict with the new regulations has not been made known to us.

E.S.R. 76: Overhead electric line conductors shall have the minimum vertical clearances above ground set out in the following table:

. . . Exceeding 650 V but not exceeding 11,000 V between phases or 6,350 V to earth — Within any borough or town district . . . 22 ft . . .

Question: Should not the words "between phases or 6,350 volts to earth" be deleted as otherwise 6,600 V earth-return lines require a ground clearance of 22 ft.

T. E. KELLY: Some amendment to the regulations is probably required to cover this point, particularly because former committees recommended that, up

to 33 kV, clearance should be the same as before (up to and including 11 kV). It is true that 33 kV requires some extra clearance, but I can see no reason why 22 and 11 kV clearances should not be the same. The additional danger is very small; in fact it is probably non-existent. I have every sympathy with this particular proposal and it should be given every support.

C. H. McKeich: This matter has been raised with the Department by some of the supply authorities with 11 kV earth return lines. Two of them have already been granted modifications as requested and a third letter has just been received. It will be granted too. The Department prefers not to amend the regulations, but to grant permission to the few supply authorities who operate this system of modification. This is the simplest way.

F. C. Stevenson (South Canterbury E.P.B.): Most supply authorities are taking 11,200 V plus from the N.Z.E.D. substations. In a court of law, how would this 22 ft clearance apply? This may be an academic point but it could arise.

C. H. McKeich: Twist that round and say that it probably applies to all voltages. I do not think that there is a simple answer and I would not like to give you one. We know that the voltage is higher than is sometimes stated and it remains a purely legal question.

E.S.R. 76 (see above): . . . Not exceeding 650 V—

Along or across any road (and including any staywire) . . . 18 ft . . .

Question: Should not the words contained in parenthesis be deleted and replaced by a clause permitting stays to be less than 18 ft when parallel with roads, but 18 ft when across them?

T. E. Kelly: This dates right back to our own committees. We studied the point long before there was any talk about poles being taken off roads. Your committees were strongly of the opinion that interference on the roads should be a minimum. If you want to get this back again it is up to you but the matter can be fairly well handled if you put poles against the fence line, and drop the staywire over the fence. This may be an evasion of the regulation, but it is getting an obstruction off the road. We have enough obstructions on them and we should clear them wherever possible. That was the considered opinion of your own committees, and it has been maintained in the regulation.

E.S.R. 77 (3): The expression "insulated for full working voltage" in subclauses (1) and (2) of this regulation shall include, among other forms of cable, insulated cables that are armoured and metal-sheathed, or both, and neutral-screened insulating cables. Where used for overhead electric lines at any voltage, cables insulated for full working voltage shall have a minimum clearance of 6 in from any building or other structure.

Question: Does trurip cable qualify for full working voltage and is 6 in clearance adequate?

T. E. Kelly: Outdoors, overhead trurip does not comply with the term "fully insulated" for full working voltage. It is only covered and was never intended to be used in situations where complete insulation is required. The 6 in clearance over a verandah dates back to the previous regulations. I do not know of any trouble or danger having arisen because of this regulation. I think it is quite adequate. Does Mr McKeich know of any accidents?

C. H. McKeich: Not with modern coverings. With older coverings we have had a few accidents but not with modern coverings. Mr Kelly and I agree on this matter of trurip. If you look in the foreword of the specification to p.v.c.-covered cables (which is probably the material used for covering trurip) you will find it is not to be considered for handling alive.

E.S.R. 82: [Restriction on use of cranes and other machines near overhead lines.]

. . . Provided that where the voltage of the lines does not exceed 33,000 V and the owner or operator . . . has been informed by the electrical supply authority . . . the minimum distance shall be . . .

Medium-voltage or any lower voltage, 2 ft.

High voltage or extra-high voltage but not over 22,000 V . . . 4 ft.

Question: Does this mean that supply authority equipment can work 4 ft from 11 kV lines?

T. E. Kelly: Yes. When this regulation was originally formulated, many years ago, supply authorities had to work within 4 ft of the lines and sometimes even less. It is unnecessary for the supply authority to notify itself, and that is the essence of the regulation.

E.S.R. 97: [Inspection and testing of earth.]

(1) The supply authority shall, every two years, examine all earth-continuity conductors and earth connections within its jurisdiction to ensure that they are effective.

(2) Earth leads and connections for the earths specified in subclause (2) of regulation 96 hereof shall be examined and tested as aforesaid at regular intervals of not more than six months.

(3) Earth leads and connections for the earths specified in subclauses (3), (4), and (5) of regulation 96 hereof shall be tested as aforesaid at intervals of not more than five years.

Question: Does the regulation convey the intended meaning?

T. E. Kelly: Yes. The regulation relaxes the previous regulations, and there may, at some later time, be justification and cause for further relaxation.

E.S.R. 101 (3) (b): Where the voltage does not exceed 650 V, either the conductors shall have an approved covering or, if the conductors are bare, they shall have a minimum breaking strength of 1,000 lb and double crossarms each provided with insulators shall be fitted at each crossing pole.

Question: Where bare conductors and strain insulators are used it is impossible to provide double crossarms "each provided with insulators".

T. E. Kelly: I do not agree with the question as surely you can have double arms and double insulators. They might both be strained. I am not quite clear what the questioner means.

R. P. Thomson (Otago E.P.B.): The regulation states that the crossing shall be provided with double arms each fitted with insulators. It would be possible to have two insulators one after the other on a single arm, but I cannot quite see how they are attached to each arm of the two.

M. D. Macphee (Manawatu-Oroua E.P.B.): Clause (c) of the same regulation says that notwithstanding anything to the contrary alternative methods may be permitted subject to the approval of the Post Office. This has been clarified in the code of practice for electric lines crossing telegraph lines. The code allows strain insulators in these particular situations.

E.S.R. 102: No apparatus associated with an electrical supply system shall be fixed to a telegraph pole without the consent of the Post Office.

Question: It is not clear if street-light brackets and other equipment, but not service lines, are involved.

T. E. Kelly: I agree that some clarification is needed. The previous regulations up to this one all referred to service lines, however, and you could safely assume that this regulation alludes to other apparatus, but I admit it is not precisely clear.

E.S.R. 19 (4): A consumer shall, without cost to the electrical supply authority, provide sufficient space on his premises to enable the electrical supply authority to install any substation, lines, or equipment necessary solely to give him a satisfactory supply but, where space is required on a consumer's premises for a substation which will also supply other consumers or premises, the provision of such space shall be on terms to be agreed between the electrical supply authority and the consumers:

Provided that the provisions of this subclause shall not prevent any electrical supply authority taking land or acquiring an easement or licence under the Act.

Question: This regulation appears to be open to various interpretations and the full legal implications should be appreciated before it is applied to any specific instance. Difficulty has been

found with the phrase "supply other consumers or premises".

T. E. KELLY: My understanding of this when it was drawn up was that if the consumer is taking the whole output he has to provide the substation site. If it is desired to supply externally as well, and the consumer had a larger load than usual, some arrangement would be made. It might be a payment for the use of the land, a 99-year lease or some other arrangement.

It might even be providing the cables which would normally be charged for. That was the intention and the regulation reads in just that manner—that you make whatever arrangement you like with the consumer, but you cannot go to him and say, "Give me the land, I am going to put a substation on it." You have to be fair about it; you divide the cost up or make some provision to him for the use of his land.

I. A. MCCUTCHEON (Wellington M.E.D.): In Wellington if it is a consumer substation only, i.e. providing for a particular building only, the owner is required to provide all the facilities. If it is a consumer service, where we are provding the network, we agree to pay on the basis of the capacity which we feed into the building in relation to the capacity which feeds into the network. We have found this acceptable and have recently had this right given to us in a local arrangement.

T. E. KELLY: This regulation was introduced because of difficulty in obtaining substation sites, particularly in the closer built-up urban areas. It was felt that a regulation would ease those problems.

E.S.R. 19 (8): Except where special arrangements . . . are made between an electrical supply authority and a consumer, the supply authority shall supply the consumer by means of an overhead or underground line according to whether its distribution lines passing the consumer's premises are overhead or underground.

Question: What special arrangements could apply to the free portion of a service line where the consumer requires an underground supply in place of an existing overhead line?

Question: Does "special arrangements" mean what it says or that *only* a supply authority may *legally* supply a particular consumer's underground service from an overhead distribution line (provided the supply authority, i.e. all consumers, pay the extra cost involved)?

Question: The regulation does not provide for the supply authority to give an underground service in an overhead area except by agreement with the consumer.

Question: The suggestion was made that a supply authority might give an underground service in an overhead area if 30 ft inside the boundary is provided free by the supply authority (see E.S.R. 20 (1)).

T. E. KELLY: The regulation is reasonably clear—in other words if the street lines are overhead, you have to supply an overhead line. If you want to put in an underground service line that is up to you; you can do what you like, but you cannot be forced to put in an underground line by the consumer. On the other hand, if the consumer wants an underground line, obviously he pays for it. If you want to give him 30 ft free, you do so of your own accord, or 60 ft, or whatever you like, but the arrangements you make with him are up to you.

J. H. BADHAM (Rotorua E.S.): The point is that a recent legal opinion states that the special arrangements referred to above do not include the power to make special arrangements for payment. This seems to confuse the regulation.

N. R. WHITE (Tauranga E.P.B.): I cannot agree with the legal opinion, and asked the General Manager for a ruling on it.

J. D. ELLIS (Hutt Valley E.P.G.B.): I can show Mr Badham a legal opinion which opposes his one.

M. D. MACPHEE (Manawatu-Oroua E.P.B.): At present we do not know where we stand. We have a legal opinion that an underground must be given if a consumer asks for it. That raises the question of what special payments you can ask for.

If you look at your regulations you will see that there is no provision for payment of a distribution line, and that is generally the portion outside the consumer's boundary, unless it is an uneconomic supply. Just how this applies to underground, I do not know. Can the consumer be asked to pay for the section down below the fence line?

On the question of the 30 ft, presumably once we get past the 30 ft we can charge for the rest of the line, provided it is for the voltage at which we supply. That brings in the question of whether it is an 11 kV underground cable which is required, or a low-voltage one. What about the portion coming down the pole? Should we try and get some guidance on whether we should give 30 ft free of charge?

T. E. KELLY: I do not think you should be too concerned with legal opinions, but interpret the regulation for yourself.

What we do is, in normal underground-reticulation areas, simply pay a contractor $9 as an offset against that free section of service. When a consumer wants an underground service from an overhead supply, and it may be across a road, we say, "You can have it; we will pay the $9 and you pay the rest." We have found this satisfactory.

E.S.R. 73: Minimum cross-sectional area and ultimate strength of conductors: . . . service lines, minimum cross-sectional area 0.01 in^2. Ultimate strength 530 lb.

Question: This minimum allows the use of No. 10 copper permitted in the 1927 regulations but not in the 1935 regulations which stipulated a minimum conductor size of No. 8.

T. E. KELLY: This is right. The question at issue is a matter of engineering. On the safety side these wires are quite satisfactory. We decided instead of putting in specific sizes to use area and strength. After due consideration of the information that was available on stranded wires, and there is possibly a greater chance of their failing, we decided that this was reasonable. It is a matter of what you consider sound engineering. Remember that these are the absolute minimum sizes.

E.S.R. 76 [Clearances above ground]: Overhead electric line conductors shall have the minimum vertical clearances above ground set out in the following table . . .

Voltage and description of lines	*Minimum vertical clearance above ground*
Exceeding 110,000 V	26
Exceeding 11,000 V but not exceeding 110,000 V	22
Exceeding 650 V but not exceeding 11,000 V between phases or 6,350 V to earth—	
Within any borough or town district	22
Outside any borough or town district—	
Along or across any road or footway	20
In any other place	18
Not exceeding 650 V—	
Along or across any road (and including any staywire)	18
Across country not normally used by vehicles	16
For last span of service lines in places not open to the public—	
In places used or liable to be used by vehicles	12
Elsewhere	9

Question: The old E.S.R.41–22 allowed 14 ft over a footpath. Should not consideration be given to the addition to E.S.R. 76 of "for the last span of service line across roads or places open to the public, but used by pedestrian traffic only . . . 14 ft."

T. E. KELLY: This is not necessary and could lead us into some difficulties. The regulation is quite practicable as it stands and does not require any further amendment. I suggest that it should be tried for a period of time.

E.S.R. 85 (2): Where an overhead electric line at medium voltage or lower

voltage is attached to a building or other structure, including a pole located adjacent to a building or structure and to which is connected any service main conductor, only conductors having an approved covering shall be used for phase or other live conductors for a distance of not less than 60 ft from the attachment of the line to the building, structure, or pole or, where the line is less than 60 ft in length, for the whole length of the line.

Question: This requires covered conductors to a 30 ft pole beside a 3 ft pump house. Where the pole extends an adequate distance, say 9 ft above the building, bare wires could be permitted as was the case with the 1935 regulations and is now the case if the conductors pass over the buildings but are not attached to a pole beside it.

T. E. KELLY: This regulation has caused a lot of discussion. It is all a question of what constitutes a building. I do not know if a 3 ft pump house is a building. You cannot enter it. You have to take the whole thing to bits before you can get in. It is simply a cover over the pump, while the essence of the regulation is safety near buildings.

C. H. MCKEICH (N.Z. Electricity Department): I agree with Mr Kelly that the regulation is confined to safety. Very many accidents have occurred where service lines were attached to buildings or structures and it was felt that this was one place in which the industry as a whole had an obligation to the consumers in the interests of safety. For that reason it had been included in this regulation which refers to poles adjacent to a building or structure in order to make certain at these points there are covered wires.

It was considered that the extra cost of the covered wire of that span was a sound investment in the interests of safety.

E.S.R. 21 (3): A consumer entitled to supply under this regulation may, instead of giving an undertaking to pay an annual sum in accordance with paragraph (a) of subclause (2) of this regulation, elect to pay a lump sum approved by the electrical supply authority but not exceeding the estimated capital cost of the extension or his proportion thereof, as the case may be, and in this event, and upon payment of the aforesaid lump sum, shall be entitled to receive a supply of electricity at the electrical supply authority's scale of charges in force in that locality.

Question: This regulation gives the consumer the right to pay for the line by way of capital contribution in one sum and then to use as little energy as suits his purpose, payment for this energy being made at the supply authority's scale of charges. This makes no provision for any minimum revenue under guarantee, as was the case in the 1935 regulations.

In certain circumstances it might be possible for lines so financed to return insufficient revenue to meet their fair share of general costs—and so operate at a loss.

T. E. KELLY: Although I was not involved with this particular guarantee section of the regulations, I know that it was considered that the idea of perpetual guarantee was not in the best interests of supply authorities despite the fact that there are many lines in the towns and in the country which do not provide sufficient revenue to cover normal costs. These lines are not under guarantee and therefore the question does arise whether your should perpetuate guarantees, and it was the considered opinion of the Revision Committee that there should be a terminal to a guaranteed period.

E.S.R. 21 (9): Paragraphs (d), (e), and (f) of subclause (2) and subclause (8) of this regulation shall not be construed so as to vary the conditions upon which any subsidy has been granted by the Rural Electrical Reticulation Council. In the case of a subsidised line, this regulation shall apply subject to any such conditions of subsidy.

Question: May it be assumed that the Rural Electrical Reticulation Council will, in cases of lines financed by capital contributions, require guarantees from consumers, or assume that guarantees are in force when calculating subsidies?

C. W. G. BEARMAN (N.Z. Electricity Department): The Council promises to pay an annual subsidy to meet losses in revenue, and it requires on the other hand to know what it is going to be and it can know that only in the light of the minimum payments made by consumers. The Council want to know its commitments and will require a statement of annual income by way of guarantee as a minimum on the consumers.

E.S.R. 77:

MINIMUM CLEARANCE OF ELECTRIC LINE CONDUCTORS FROM A BUILDING OR OTHER STRUCTURE

Voltage of line	*Without a warning notice fixed to the building or other structure*		*With a warning notice fixed to the building or other structure*	
	Vertical	*Horizontal*	*Vertical*	*Horizontal*
	ft in	ft in	ft in	ft in
220,000	16 0	12 0	12 0	10 0
110,000	12 6	8 6	10 0	8 0
66,000	11 0	7 0	9 0	7 0
50,000	10 6	6 6	8 6	6 6
33,000	10 0	6 0	8 6	5 6
22,000	9 6	5 6	8 0	4 0
11,000	9 0	5 0	8 0	4 0
6,600	8 9	4 9	8 0	4 0

Question: Are these clearances dangerously small? What of high-voltage conductors over flat roofs?

Question: The definition of a service line appears to rule out the former concept of a "chargeable high-voltage service line".

Question: If this is so, what is the view of the Rural Electrical Reticulation Council in regard to h.v. construction beyond 60 ft?

T. E. KELLY: You will find that the clearances are increased above 6,600 V except when a warning notice is fixed to the building.

I assume that the h.v. conductors are those between 660 and 6,600 V and I think the original clearances were 7 ft 6 in. I cannot see that there is any increase of danger over the previous regulations and I am not aware of any hazard that has been created in the past.

The only way to tackle the third question is to have a fully-paid-up guarantee and this should be continued.

I presume that the Council would take the view that such construction is not a service line, as a service line is strictly defined?

C. W. G. BEARMAN: Yes.

Regulations 19 and 20: [Supply to consumers and standard conditions of payment.] Service lines.

T. E. KELLY: Although it is perhaps out of place, I want to comment on a recent legal opinion regarding Regulation 19 (6) (c). 19 (6) (a) refers to service lines originally paid for by consumers, etc. Regulation 19 (6) (b) refers again to Regulation 20. Regulation 19 (6) (c) on the other hand, does not refer to Regulation 20, and in effect covers all service lines that were constructed either under guarantee or under payment by the consumer. The original intention was that a line constructed under guarantee belonged to the supply authority, and if it was necessary to increase its capacity, it was the duty of the supply authority to do it. But according to the opinion, where a line is constructed under guarantee and a low-voltage line or low-voltage service line is constructed into a property under guarantee, the cost of conversion to 11 kV can be charged to the consumer.

There is also the question of a service line serving people in a back section or down a right-of-way. Can a service line supply more than one consumer or does a shared line automatically become a distribution line? The legal opinion gives the view that a service line serving several people is in fact a distribution line. I do not think that is correct. If it is off the road it is a service line, although each consumer is entitled to his proper share of it, i.e. 60 feet.

M. D. MACPHEE (Manawatu-Oroua E.P.B.): The implications of a service line and Regulations 19 and 20, particularly in regard to the special arrangements, are still not as clear as we would like. There is no unified approach to them, and it would be useful to have further discussions on this in the regions.

Mr Macphee moved:

THAT the implications of Regulations 19 and 20, in particular "special arrangements" (19 (8)) be referred to the regions for further discussion.

Seconded Mr White and carried.

J. D. SNELL (Franklin E.P.B.): In Regulation 17 there does not seem to be any redress to the consumer in the event of a dispute between the supply authority and the consumer. It was mentioned in the old regulations that the consumer had the right of appeal to the General Manager of the N.Z. Electricity Department.

T. E. KELLY: I believe that there is something, covering the whole of the regulations, which says anybody can appeal to the General Manager concerning their application.

C. H. McKEICH (N.Z. Electricity Department): There is no appeal written into the regulations.

T. E. KELLY: Does any supply authority want to force its will on the consumer in such a manner that the right of appeal is denied?

J. D. SNELL: Would the Department accept it, if the supply authority thought it was right?

C. H. McKEICH: We have already had complaints since 1 April and we do not refuse them. Once the complaint is made, we try to do something about it as otherwise it will go from the consumer to a Member of Parliament.

N. R. WHITE (Tauranga E.P.B.): Legal opinion has been sought twice in regard to a low-voltage refrigerator motor burnt out, and a deep-freeze unit. In the most recent case the legal opinion suggests that whether or not the supply authority was notified, it is responsible. But in the earlier opinion there appeared to be a slight conflict with this. After all such legal opinions are the opinion of only one person.

T. E. KELLY: It is true that legal opinions vary and I feel that a legal opinion is almost a last resort only.

The New Standards Association

E. H. HITCHCOCK, B.E., D.P.A., C.Eng., M.I.E.E., M.N.Z.I.E.
(Chief technical adviser, Standards Association of N.Z.)

THE Standards Association of New Zealand has been set up under a new Act as a result of representations from many organisations. It completely replaces the old Standards Institute which was a division of the Department of Industries and Commerce. The Association is an independent statutory body set up under its own Act, and it has been officially in existence for 18 months. There was a long transition period, and the Association is only now gathering strength. There are many things to be done.

The 1965 Act set up the Association, which consists of a Council, committees of Council, and members. The Council includes a representative from the Electrical Supply Authorities Association, and its president is a very good and active member on the Council. The Council of the Standards Association now has the power to make its own rules and to appoint staff with terms and conditions agreed with the State Services Commission. The staff are not public servants.

The Standards Council now has power to prepare, promulgate and declare standards as New Zealand standards—previously the prerogative of the Minister of Industries and Commerce—and to fix subscriptions of the members of the Association. The new Association has been working in fairly difficult circumstances. Our staff is smaller than before, but we are hoping to build this up.

The financial independence has meant some very serious changes. We now have a grant from the Government and we hope that as the membership of the Association grows the contributions from industry and members generally will provide a comparable amount.

Some very large organisations have joined the Association and shortly there will be a general campaign for membership. The present economy measures have not been conducive to a new organisation getting under way. A number of the services which were afforded the former Standards Institute by other sectors of the Government were not paid for at cost.

This arrangement has now been terminated and the new Association is working entirely independently—a very healthy situation. It presents some difficulties, but from the point of view of realistic allocation of cost and effort it will be a great improvement.

The independence in rules gives the Council a much greater flexibility in dealing with its committees. The sectional committees will have the principal function of recommending to Council proposals for Standards in their particular field. They will pursue the need for standards in that field and recommend on the means of developing those standards.

We hope they will be very much involved with follow-up of actual effects of standards in operation.

With regard to overseas standards—a burning question for many years—the new Act permits us to adopt almost exactly what your Institute recommended at its conference in 1959.

There were many representations to the former Standards Institute for improved procedure without result. Now when overseas standards are needed in New Zealand and they are suitable for use without amendment, they will merely be endorsed "Suitable for use in New Zealand." This can be done by placing a label on the front. It will be a simple procedure. There will be no declaration of the standard as a New Zealand standard, and there will be no allocation of a New Zealand number. This will be welcomed by all engineers.

If an overseas standard has to be amended for New Zealand use, it can then be given its New Zealand number and declared a New Zealand standard just as at present. British standards that are either endorsed "suitable for use in New Zealand" or declared as New Zealand standards will be noted in the "BSI Yearbook" as at present, with the symbol NZ, plus a footnote if amended for local use.

The new Association must take care with its stocks, and we propose to use the endorsement and declaration as the controlling factor in holding stocks. We

will hold stocks, and will endeavour to have available over the counter at all times any standards that have been endorsed suitable or declared as New Zealand standards. If standards have not been so designated, stock will be reduced.

Both the endorsed and declared standards will be included in the index published by the Standards Association of New Zealand.

The Association hopes that Committee members and members of your Institute, will come forward with any suggestions for the streamlining of operations. We hope to call for technical assistance on committees in all sorts of flexible ways, in addition to augmenting our permanent staff.

We hope to set up some sort of a referee system for standards, particularly international standards, so that comment can be asked for from those willing to do so.

We hope to streamline procedure to cut out some of the three-tier systems of approval, and speed up procedure generally.

We are looking at the Standards Mark procedure, and hope to enlist the skill of technical committees in devising systems for the Standard Mark testing so that these tests will be adequate and efficient.

One complex problem we are looking at is the use and application of standards in law and in by-laws. There is much to be done here, and I am particularly interested in developing techniques of using standards as a means of applying technical law. We look forward to a period of very active cooperation with your Institute and hope we can make the Standards Association a vigorous and active body contributing to the welfare of all.

Discussion

M. G. KEYS (Auckland E.P.B.) All of us use British Standards very widely in our specifications, and from time to time there is need to obtain another British standard because of some peculiar or particular feature which we wish to introduce into our specifications. Up till now we have had no difficulty in obtaining the particular British standard we require. Is the innovation referred to by Mr Hitchcock going to mean that the Standards Association will hold fewer British standards and that delays will occur? That would be extremely regrettable.

What does membership of the Standards Association mean? Will members obtain additional facilities or inside information that would not be available to the public? Do you have to be a member before you can avail yourself of the facilities of the Association, or before you can buy a New Zealand standard or a standard from overseas?

E. H. HITCHCOCK: The proposal should not mean fewer standards held in stock. With the proliferation in standards there must be some selectivity exercised, because the previous holding of the former Standards Institute was 30 copies of every British standard. You will agree that this was absurd. We have to make some selection of what we are going to hold. The general criterion will be whether the standard has been endorsed or declared. We envisage that any standard which is in use in New Zealand should have been reviewed by a committee and be endorsed "Suitable for use in New Zealand" if not adopted as a New Zealand Standard.

This will deal with, say, 90% of the standards on which we have to take a decision. The remaining 10% are going to be awkward, and we propose to arrange for our technical advisers to give advice to our sales department on any special case where they feel that a standard is obviously going to be widely used in New Zealand, even if for some technical reason it is not going to be endorsed or adopted, so we hope, with the judgment of our technical officers, that we will fill in all the gaps Mr Keys is worried about; but at the same time the endorsement/adoption process will be a general sorting out of the standards we feel we should hold in stock.

The privileges of membership are still being discussed and the rules being developed but, in general, it is envisaged that the Standards Council must carry out its responsibility in terms of circulation and publicity for standards, without any serious limitation to members only. On the other hand we must arrange for some privileges for membership. At the moment it is envisaged that members will be entitled to borrow on loan from our library. This would mean that although any individual could consult works in our library, the actual sending of documents out on loan would be restricted to members.

It is envisaged that we should have something in the nature of a monthly news-sheet to members, carrying notification of standards earlier than in the *Bulletin*. Discussion is still going on as to whether the free amendment service should be limited to members.

W. LANGBEIN (Wairoa E.P.B.): Where does Mr Hitchcock get his finance?

E. H. HITCHCOCK: At present a Government grant provides finance approaching the level of previous support, although there has been an economy cut.

It is envisaged that the expansion of the Association's work must be carried out from subscription from members. This is very much in line with most standards associations in other countries; in other words, industry and Government in partnership contributing towards the operation of standards.

Votes of thanks

W. M. E. MIRAMS (moving a vote of thanks to the host authorities—namely Ashburton E.P.G.B., Central Canterbury E.P.B., Christchurch C.C., Heathcote Co.C., Kaiapoi B.C., Lyttelton B.C., North Canterbury E.P.B., Rangiora B.C., Riccarton B.C., South Canterbury E.P.B., Timaru C.C.):

It is a very real privilege to have this opportunity of thanking the host authorities who have made our stay in Christchurch so pleasant. Most of us have been to Christchurch before, many of us have studied here, and all who have been here previously will have been looking forward to coming back to this city. It is a very beautiful place, particularly at this time of the year, and that combined with the weather and excellent arrangements that the host authorities have made for our convenience and pleasure, have already made this conference a very enjoyable one.

M. G. KEYS: It is my pleasure to thank all who have worked to make the conference so successful. I refer to all those people who have worked before and during conference and will have to work after conference. An enormous amount of work goes into the preparation of a hall and all the other matters that have to be handled before a conference is to be held and this sort of work continues right throughout the conference, and there is the tidying up afterwards. The Christchurch M.E.D. has been responsible for much of this work and we are indebted to Mr Shelley and his staff for what they have done. There are a considerable number of people whom we never see and these are just as important to the successful operation of a conference as those whom we do see.

Those that we do see include the operators of the public address system and of the projector. Then we have had very good service from the lady receptionist at the door.

In addition, we have had the very good service of our two lady recorders, and we are grateful for the pleasant way they have recorded our proceedings, also the press. To all these people conference is greatly indebted.

Installation of new president

C. L. WALTER: In installing Mr Anstice as president of the Institute, it is appropriate to recount his achievements and experience.

S. R. ANSTICE, C.ENG., F.N.Z.I.E., M.I.E.E., F.N.Z.I.M., was educated at the University of Canterbury and after serving an engineering cadetship with what is now the N.Z. Electricity Department, joined the Dunedin City Electricity Department in 1939 as an assistant electrical engineer. Except for service in the R.N.Z.A.F. in New Zealand and the Pacific, mainly as a radar officer, Mr Anstice has been with the Dunedin City Electricity Department ever since. In 1946 he was promoted design engineer and it was in this capacity that he won the Institute's award in 1952 for his paper on the Dunedin C.C. Neville Street 33 kV substation. Mr Anstice was appointed deputy city electrical engineer in 1955 and city electrical engineer in 1957. In 1965 he became general manager of the Electricity Department.

He was elected to the Institute executive in 1957 and has been a vice-president since 1963. He is an Institute nominee on the Electrical Supply Authorities Association committees dealing with natural gas, power and finance utilisation; the deputy engineer member of the Electrical Development Association council, and one of the supply authority members on the Government Power Planning Committee. He is a member of the Electric Linemen Training Committee and the N.Z. National Committee of the World Power Conference. He is at present convener of the Institute's Power Supply and South Island Injection Frequency Committees.

Mr Anstice was elected to the executive of the N.Z. Institute of Local Authority Administration last year.

He visited the United Kingdom in 1964 as a guest jointly of the Board of Trade and the British Electrical and Allied Manufacturers Association.

As you can see, Mr Anstice has been a tireless worker and in addition he has always been very helpful to all. As president over the last two years I am deeply indebted to him for his very willing assistance and help, and I now have pleasure in installing Mr Anstice as your president for the next two years. I trust his time as president will be as happy as mine has been.

S. R. ANSTICE: One must always approach the start of a period as president of an organisation such as ours with some doubt as to one's ability to meet the demands that are made on the occupant of this office. I can assure you that I do have these doubts in no small measure.

However, at the same time, I am very conscious of the honour you do me in making me your president, and I in turn wish to thank you for the confidence that you have shown in me, and to assure you that I will do my best to live up to the high standards that have been set by the previous presidents of this Institute.

Our industry is faced with a number of problems. Some of these are of our own making and some come to us because of outside pressures. However, I like to think that all our difficulties arise from the fact that we are making progress.

In the past two years Mr Walter has had to come closely to grips with many of the current problems and some of us have seen how he has tackled them, with credit to himself and with credit to our Institute.

As you are aware, Mr Walter will shortly retire. In fact on this occasion Mr Walter is the only representative of a member authority who will retire before the next conference, so I must make reference to the fact that with very considerable regret we farewell him from amongst us.

Thus I will couple with these thanks our gratitude to him for the services that he has rendered over the past two years as our president, and our thanks to him for his activities over a very much longer period. If we think back we will know that his contribution has lasted over the whole period that he has been a member of this Institute. We need to remember that it is not only in these last two years that he has done so much for us and the industry, it is over the whole period that he has been a representative of an Authority and a member of this Institute.

I would now move a very sincere vote of thanks for the very conscientious and effective way he has served us as our president over the last two years. And I will couple with this vote of thanks to him, thanks for his contribution over the longer period of his membership of this

Institute, and I would like to wish him and Mrs Walter a very long period of retirement and a very happy period.

C. L. WALTER: Thank you very much, Mr President, for your kind remarks, and to you, Gentlemen, for your endorsement. It is going to be hard pulling out of the electrical supply industry because over such a long period one makes friends such as one seldom does in any other industry.

Thank you, Mr President, for your remarks about my term as president. There have been problems, as there always have been and always will be. One of the great virtues of our Institute is that we operate as a team and I am very grateful for the help I have been given.

In conclusion, I would thank you all for the honour and privilege to have served as your president, and I do very much appreciate the assistance given to me by the president of the Electrical Supply Authorities' Association (Mr Gooder) and the secretary-manager (Mr Heir), and the president of the Secretaries Association (Mr Boswell) also. There is liaison there and the help when required.

To the past presidents of the Institute and to the members of the Executive Committee and members of the Institute, I offer thanks for your help and assistance and last but not least to our tireless and energetic secretary on whom I must confess the greater weight of the burden falls—I am deeply indebted to him for his assistance and cooperation over my term.

Although I will be out to grass, I will naturally be watching the activities of the Institute in particular and the industry in general with great interest, and I wish you every success and happiness in the future.

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THE PRESIDENT: This concludes the business of the 38th annual conference and I now declare it closed.

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